SOCIETY FOR THE ENCOURAGEMENT OF ARTS, MANUFACTURES, AND COMMERCE.

CANTOR LECTURES

ON

COMMERCIAL FIBRES:

THEIR HISTORY AND ORIGIN,

With Special Reference to the Fibre Industries connected with Her Majesty's Colonial and Indian Possessions.

BY

D. MORRIS, C.M.G., M.A., D.Sc., F.L.S.,
Assistant-Director of the Royal Gardens, Kew.

Delivered March 18, 25, *and April* 1, 1895.

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SYLLABUS.

LECTURE I.

Commerce in fibres—Origin of fibres—Foreign and British fibres—Capabilities of Colonies for production of fibres—Systematic investigation of fibres—Works relating to fibres—Collections at Kew—Essential elements—Cellulose and non-cellulose constituents—Fibre bundles and fibre cells—Botanical investigation—Chemical investigation—Pure cellulose in seed hairs, in bast fibres, and fibro-vascular bundles of endogens—Fibres of Dicotyledons or exogens—Seed hairs, American cotton, Asiatic cotton—Kapok and vegetable silks—Bast fibres (higher textiles) flax, common hemp, Madar fibre, Rajmahal hemp—China grass and Ramie—Distinctions both in plants and fibre—Other nettle fibres: tashiari, Nilgiri nettle, poi, ban-rhea, ban-surat—Urera fibre, mamaki, rere—Sunn-hemp—Lower textiles: Jute, Hibiscus fibres, Dunchi hemp, Ko hemp, Malu fibre.

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COMMERCIAL FIBRES.

LECTURE I.—DELIVERED MARCH 18, 1895.

The commerce in fibres is admittedly of great importance. It is one of the largest in the United Kingdom. The total imports of raw fibrous material during the year 1893 was of the value of £50,000,000 sterling. The total exports—chiefly manufactured goods—were of the value of £74,000,000 sterling. Hence the total turnover in fibrous substances in 1893 was of the estimated value of £124,000,000 sterling. Of this large amount, India and the Colonies contributed about 10 per cent. of the imports. The Table given below will indicate the sources whence the fibrous materials received in the United Kingdom were derived:—

VALUE OF IMPORTS DURING THE YEAR 1893.

	Foreign Countries.	British Possessions.
	£	£
Cordage material	502,145	185,475
Cotton, raw, yarn, &c....	34,618,079	1,202,790
Flax, raw, &c.	1,103,377	1,474
Hemp, &c.	2,213,735	238,022
Jute	3,721,973	3,640,185
Paper material:—		
Esparto, wood-pulp, &c.	2,054,696	*40,170
Linen and cotton rags..	199,155	4,859
Pulp of rags, &c.......	231,119	44,990
Total	£44,644,279	£5,357,965

Summary.

Foreign countries	£44,644,279
British possessions	5,357,965
	£50,002,244

The small proportion of fibrous substances received from British possessions is very striking. This is not due to the fact that fibres were unsuited to the circumstances of Colonial and Indian industries. India itself grows immense quantities of cotton, but 42 per cent. of it is shipped to foreign countries. There is no doubt room for considerable expansion in the cultivation of fibres in British possessions. For instance, the Dominion of Canada is capable of growing excellent flax, specimens of which were shown at the Colonial and Indian Exhibition of 1886. Natal possesses a local variety of hemp (*Cannabis*) of singular merit for textile purposes. Queensland can produce a *Sida* fibre better than Indian jute. Victoria, in the north-west portions of its territory, has promising lands for flax-growing that would support an industry far more profitable than wheat growing; while New Zealand has only to make its Phormium fibre available for the higher textiles to establish an industry of the greatest value. The plant is abundant everywhere in a wild state, and it is a most persistent member of the local flora. Its systematic cultivation is, therefore, hardly necessary for some time to come. The Maori cleaned fibre is better selected and better prepared than the machine fibre, and this indicates the direction in which improvement should take place.

The West Indies are finding it difficult to grow sugar to compete successfully with beet sugar, and if a change of culture were imperatively demanded, some of the islands could grow the best sorts of sea-island cotton, and so go back to the position of a hundred years ago, when the West Indies supplied nearly all the cotton required for the world's markets. It is also open to them to grow ramie, pre-eminent amongst vegetable fibres for strength, fineness, and lustre.

In the Bahamas a large effort is being made to grow Sisal hemp, a valuable white rope fibre extensively used both in this country and in the United States. Mauritius hemp has been produced for many years, and the industry has been well sustained in spite of periodical depression in prices. West Africa has lately

* Wood pulp from Canada.

produced from the wine palm a bass fibre of considerable value. This is obtained also in Ceylon and India from the Palmyra palm. In all these possessions the prospects of development are encouraging, provided, however, the industries are not overloaded with capital, and the cost of production is reduced within the lowest possible limits.

Commercial fibres have hitherto been regarded as a heterogeneous group of natural phenomena. They have been studied piecemeal, rather than in a systematic manner based upon the morphological or chemical character of their constituent elements. Botanically, they might be dealt with according to the sequence of the natural orders of the plants yielding them. Such a plan should not, however, be strictly followed, as we would have to deal at one time with different sorts of fibres—say bast fibres and seed hairs—yielded by one and the same plant. While, therefore, the botanical arrangement will, in the main, be followed, it will be necessary to depart from it whenever certain morphological and structural distinctions arise requiring special treatment.

Vegetable fibres have received considerable attention of late years. Numerous writers have described their origin and characteristics, and a large mass of information has been accumulated respecting them. The fibres of our Indian Empire have been specially studied. Two early investigators in the field of fibre research are deserving of special mention. Dr. Hugo Müller, in "Die Pflanzenfaser" (Brunswick, 1876), a work that first appeared as a report on the vegetable fibres at the Vienna Exhibition of 1873, may be said to have started the chemical method of examining commercial fibres and laid the foundation of much of what has been done since that time. The late M. Vétillart ("Etudes sur les fibres végétales textiles," Paris, 1876) investigated the microscopic structure of commercial fibres, and drew careful and accurate deductions between the structure of the fibres and their value in commerce.

Since 1876, the field of investigation, from the chemical side, has been successfully occupied by Messrs. Cross and Bevan. The former prepared the official report for the Royal Commission on the miscellaneous fibres shown at the Colonial and Indian Exhibition, 1886, and was further associated with Dr. George Watt, in the preparation of a "Report on Indian Fibres and Fibrous Substances," published separately (London: Spon, 1887). Quite recently Messrs. Cross and Bevan have published a valuable text-book on "Cellulose" (London: Longmans, 1895), giving an outline of the chemistry of the structural element of plants, with reference to their natural history and industrial uses. The botany of vegetable fibres, especially in regard to those that have come into prominent notice of late years, has been very fully treated in various articles in the "Kew Bulletin" (London: Eyre and Spottiswoode, 1887-95). Detailed information respecting the fibrous plants of India may be obtained from Watt's "Dictionary of the Economic Products of India," vols. I.-VI. (London: Allen and Co.); while general information may be gathered from Spon's "Encyclopædia of the Industrial Arts," 1881, in a series of articles on "Fibrous Substances." At the close of these articles there is a very extensive bibliography of works dealing with vegetable fibres.

In works treating of the economic properties of tropical and sub-tropical plants nothing is more common than the references frequently made to the fibre-yielding properties of these plants. There are, no doubt, thousands of plants capable of yielding fibres of some sort. For instance, we are informed that there are over 300 fibre-yielding plants found in our Indian empire. Of these at least 100 are said to afford strong and useful fibres, which are regularly used by the natives of India. Only 30 are, however, worthy of European recognition, while those actually utilised for commercial purposes do not exceed ten.

The total number of fibres employed in European manufacture is singularly small. In fact, it is little more than it was fifty years ago. Some new fibres have no doubt been introduced, but they are, in many cases, of lower textile value, and have been chiefly used as adulterants of the more expensive and higher fibres. A great change has, however, taken place in the quantity actually produced of all fibres, and, as already shown, the commerce in fibres is now of great importance. The principal vegetable fibres in order of commercial value are—cotton, jute, flax, hemp of different sorts, paper material (esparto and wood pulp), cordage material, coir and brush material, and raffia. This is a singularly small list.

It has been asked whether the general neglect of many really valuable fibres known to exist in many parts of the world arises from some defect in the cultivation, in the want of suitable appliances to extract the fibre, or in

the incidents of distribution and commerce. It is difficult to understand why some undoubtedly valuable fibres have hitherto been quite neglected. The fibres themselves have been carefully and exhaustively examined, and they have proved of great merit. In spite of this, however, they are still unknown in commerce, and such an intrinsically inferior fibre as jute occupies a position second only to cotton or flax.

It will be the object of these lectures to bring into prominence several fibres quite as deserving of notice as those already in use. They will be found to possess qualities in some degree superior to those now in commerce, while their special adaptation for cultivation on a large scale in British possessions in the tropics should bespeak for them the attention they deserve.

Those anxious to study the plants yielding commercial fibres cannot do better than visit the large collections—possibly the most complete existing anywhere—at the Royal Gardens, Kew. Specimens of nearly all the plants mentioned in these lectures are to be found there, in a living state, duly labelled. In the Museums of Economic Botany I. and II. may be seen the fibres themselves, in different stages of preparation, as well as the manufactured articles prepared from them. The guide-books to the museums (obtainable at the entrance gates) indicate exactly the portions of each museum where the specimens are to be found. Students and men of business can thus make their own observations in this country almost as well as if they visited the tropics.

Essential Element in Fibres.

In spite of the complexity and variety of the fibres known in commerce, and the different forms presented by the plants yielding them, the essential element on which their value depends is always the same. A fibre, to be of value, must consist of a substance known chemically as cellulose. The larger the percentage of cellulose, and the purer the quality, the better, in a general sense, is the fibre.

Cellulose has been described as the substance which constitutes the essential part of the framework of plants. In the young cells of plants the wall is formed of a delicate, but firm and elastic membrane. This wall consists of cellulose, which is, chemically, very similar to starch. The strength and elasticity of all parts of plants are ultimately due to the cell-walls, which serve as a firm supporting framework for the whole structure. During the process of growth in plants, many cells become incrusted with colouring matter, resins and other substances, which, in some parts, as in the heart wood of trees, fill up the entire cavities. Some tissues, however, remain with little or no incrustation, and, although their walls are thickened, they consist almost wholly of cellulose. We have good examples of such cells in the perisperm of certain seeds, such as those of the ivory palm and the date palm, and in the pith of the rice-paper plant (*Fatsia papyrifera*) and the shola or pith helmet plant (*Æschynomene aspera*). The fine floss of cotton, kapok, and the seed hairs known as vegetable silks, are almost pure cellulose, as also such manufactured vegetable fabrics as linen, hemp, and unsized white paper. Cellulose, in its more compact form, is not coloured by solution of iodine, but if previously disintegrated by sulphuric acid or caustic alkali, it produces a violet-blue colour with iodine. This serves as a convenient test for cellulose in all microscopic preparations.

Cellulose, perfectly purified, is white, translucent, and of the specific gravity of about 1·5. It is insoluble in water, alcohol, and oils, both fixed and volatile. Well bleached linen is composed entirely of cellulose, hence its value for paper-making. Under ordinary conditions of the atmosphere cellulose is practically indestructible. For instance, in the Kew Museum, pieces of linen rags are shown taken from between undisturbed bricks in the temple of Hawara, built B.C. 2500. They are thus over 4,000 years old. Cellulose is disintegrated by means of acids, hence vegetable fibres can be distinguished from those of animal origin, such as wool or silk. From a wool-cotton fabric the cotton is easily separated by soaking the fabric in dilute sulphuric acid. The disintegrated cellulose is removed, leaving the wool unaffected. The actual amount of cotton in a wool-cotton fabric can be thus estimated. The capability of cellulose of being gelatinised in cupro-ammonium solutions, and rendered of industrial use in "Willesden" and other goods, will be discussed later.

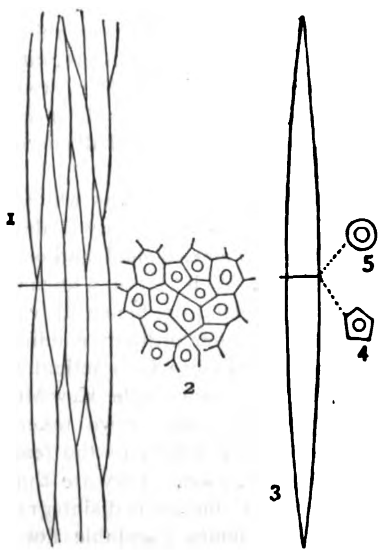
Fibre Bundles and Fibre Cells.

Although cellulose is found in all parts of plants, the parts that are of special value for yielding commercial fibres are certain cells which occupy a definite area in each plant, varying, however, greatly in the extent and form of distribution, as well as in the length,

thickness of cell wall, and the nature of the adjacent tissues.

Fibrous cells are usually long, thick-walled cells, with sharply, or sometimes bluntly, pointed ends. The wall is generally thickened all over, but there may be a few small, narrow pits, where the wall is left thin. The fibrous cells, unlike the vessels (through which the nutrient fluid passes to build up the plant), keep their living contents, and do not fuse with one another. They are, in fact, long narrow tubes, tapering at both ends, holding a fluid sealed up in the central cavity. The chief function of the fibrous cells in plants is a mechanical one; they serve merely to give rigidity to the plant, and prevent it from collapsing.

FIG. 1.



DIAGRAMMATIC REPRESENTATION OF A FIBRE BUNDLE.

1. Longitudinal aspect showing the arrangement of the cells. 2. Transverse section exhibiting the relative position of the individual cells, the thickness of the cell wall, and the cavity. 3. An isolated fibre cell, much enlarged. 4. Section of a cell showing the polygonal form due to compression. 5. The normal form.

Fibrous cells overlap one another, and form, in the mass, a tissue, called prosenchyma. Numerous instances, showing the position and arrangement of fibrous cells, will present themselves later.

In the great division of plants known as Dicotyledons (having four or five parts to the flower, and the veins of the leaves forming a network), the fibrous cells are to be found in the middle layers of the bark. In such parts are to be found the fibrous, or bast cells, of flax, hemp, jute, China grass, and paper mulberry.

In Monocotyledons (with parts of the flower usually three or six, and the leaves with parallel veins), the fibrous cells (Sclerenchyma) are found built up with vessels into a composite structure known as a fibro-vascular bundle. These bundles are irregularly distributed in fleshy leaves or in stems, and are not localised into a continuous tissue as in the Dicotyledons. The fibre-yielding plants amongst Monocotyledons are grasses, agaves, and other amaryllids, musas, and palms.

In extracting fibre from plants by any process that will break up the tissue in which they are built up, the first aggregate that presents itself is a fibre bundle. This is composed of a number of cells adhering together and forming the unit from which the spinning thread is formed. In a cross-section a fibre bundle shows a number of cells with walls more or less thickened, and a central cavity. Owing to the pressure to which the cells have been exposed, the walls are usually hexagonal, not round. *See* Fig. 1 (4 and 5). If a fibre bundle is treated with alkalies it will be resolved into its component units, and we have the ultimate fibre cell. In cotton and other seed hairs the ultimate cell is already isolated as an elongated tubular body attached to the seed. In bast tissues, as has been shown, the ultimate cell is obtained only by a thorough disintegration by means of alkalis.

As regards the fibre bundles (being the spinning units), it is of great importance that they should be uniform as regards length and diameter. Further, they should have tenacity, flexibility, and smoothness, so as to give them good spinning qualities. The fibre cells, on the contrary, are to be examined first for length, then for thickness of wall, size of cavity, tapering ends, and, lastly, for uniformity in size and composition. Perhaps the most important factor of all is the length of the ultimate fibre cell, for although it is not the spinning unit, it is in a very direct sense the essential factor of strength and durability of the manufactured goods. In the subsequent process of bleaching the fibre bundles are disintegrated and the individual cells isolated. As a striking instance of the value of length in the fibre cell we may compare the fibre cells of jute and flax. In jute they are only 3 mm. long, in flax they are 40 mm. long. In the case of jute, according to Messrs. Cross and Bevan, bleaching means "rotting"—that is, the whole fabric falls to pieces.

Investigation of Raw Fibrous Materials.

The first step necessary in the investigation of plants for fibre purposes is to determine the position of the fibre bundles and their relative abundance in regard to other tissues. In the case of Monocotyledons, sections would have to be taken across the leaves, petioles, or stems. In Dicotyledons the stems alone are likely to yield fibre, and these only in the peripheral layers of the cortex encircling the woody parts. The further examination requires some care.

Very valuable hints respecting the histological examination of fibres are given by M. Vétillart in the work already cited. An abstract of his methods, revised by the author himself, is published in Christy's "New Commercial Plants," No. VI. (1882). These are methods for the microscopical and structural investigation of fibres. Although useful in determining the relative abundance of the fibre bundles and the length and character of the fibre cells, they are by no means sufficient to afford a complete idea of the value of the fibre. To do this it is necessary to adopt chemical tests and carry them out with the precision which necessarily attaches to scientific measurements. Messrs. Cross and Bevan have remarked that "systematic inquiry, based upon uniform method, must contribute more than anything to the scientific development of a subject." We cannot do better than recommend for general use the more elaborate method found so successful by these original investigators. The Cross and Bevan method of chemically investigating vegetable fibres is fully explained in "Cellulose," part. iii., pp. 242-310. It is admitted that a microscopical examination is necessary also. A review of the structure and anatomy of exogenous and endogenous plants must therefore precede, or at least accompany, the chemical investigation.

Botanical Investigation.

The distribution of the fibre bundles in the plant itself having been ascertained, the next point is to extract the fibre by mechanical or chemical means, and have it carefully washed and dried. A fibre thus extracted would consist of numerous threads, each of which would represent a fibre bundle or filament, and form the unit for spinning purposes. The general appearance of the fibre in this state, the softness and fineness of the filaments, their strength, colour, and lustre, are at once appreciated. If the fibre is entirely new, the further examination necessary would be under the microscope. It would be useful, for this purpose, to have both a dissecting microscope, with a lens magnifying 10 to 15 diameters, and a compound microscope, with lenses magnifying up to 300 diameters. The eye-piece of the latter should be fitted with a micrometer. The reagents necessary would be a solution of iodine, sulphuric acid, glycerine, carbonate of soda, and caustic potash. The first point is to determine the number of fibre cells to each bundle, and the nature of the surrounding tissue. In some few cases the cells may be single, or in groups of two or three; in others, they may be in bundles of 30 to 50, more or less agglutinated together. A cross-section would also show the size or shape of the cavity of each cell, the thickness of the cell wall, and the characteristic markings—such as concentric rings, if any—present. Each cell should now be carefully isolated. Its length, as already mentioned, is of great importance. The operation of measuring should therefore be repeated, according to the degree of approximation required. The extreme, as well as the average length, should be duly noted. The diameter of the cell is of less importance, but is also necessary.

Chemical Investigation.

The aim of a chemical investigation of fibres should be to determine the quantity and quality of the cellulose and its chemical characteristics. These are of primary importance. Other points are subsequently investigated, and on the total results thus obtained are based the appreciation of the fibre and its possibilities as an article of commerce.

The points to be dealt with are as follows:—

1. *Moisture*.—This is the water of condition or the hygroscopic moisture taken up by a fibre after being dried at a temperature of 110°. Textile fibres of the highest class are distinguished by their relatively low moisture. It might be mentioned that dry wood-pulp in commerce contains, in an ordinary atmosphere, 10 per cent. of hygroscopic moisture.

2. *Mineral constituent*.—This is the percentage of ash left after burning the fibre. The lower the per-centage the purer the cellulose.

3. *Hydrolysis*.—This is a bleaching process, in which one portion of the fibre (*a*) is boiled in an alkaline solution for five minutes. The loss of weight shows the proportion of the

fibre which yields to the solvent action of the alkali. Another portion of the fibre (*b*) is boiled for one hour. The loss of weight in the latter case gives the "degrading" action of the alkali.

4. *Cellulose.*—A specimen of fibre having been boiled in dilute alkali, as indicated above, is well washed, and exposed for an hour, at the ordinary temperature, to an atmosphere of chlorine gas. "It is then removed, washed, and treated with a solution of sodium sulphite, which is slowly raised to the boil. After two or three minutes' boiling, it is washed, dried, and weighed." The per-centage yield of cellulose, on the raw fibre, thus obtained, is the most important criterion of its composition and value.

5. *Mercerising.*—This shows the action of concentrated solutions of alkalis upon vegetable fibres. This was first studied by Mercer, hence known under his name. The action is noted in regard to the loss of weight sustained.

6. *Nitration.*—Fibres exposed to the influence of a nitrating acid (a mixture of equal volumes of concentrated nitric and sulphuric acids) increase in weight. They also acquire various colours. The net increase in weight varies from 5 to 55 per cent.

7. *Carbon per-centages.*—Accepting cotton as typical cellulose, the amount of carbon obtained by ignition is 44·4 per cent. The lower carbon per-centages are from 40-43; the higher, 45 to 50.

8. *Acid purification.*—To clean the fibre, and remove all accidental impurities, it is heated to boiling point in a 20 per cent. solution of acetic acid. It is then dried and weighed. The loss in weight sustained shows the impurities present.

I. SEED-HAIRS.

From the morphological point of view the fibres of commerce may be either seed hairs, the bast fibres from the inner bark of Dicotyledons or the fibro-vascular bundles from the stems, petioles, or leaves of Monocotyledons. On the other hand there is also a commercial classification. In this the various fibres are grouped as follows:—(1) the higher textiles, such as cotton, flax, common hemp, Sunn hemp, and China grass; (2) the lower textiles, such as jute, Abutilon hemp, and Deccan hemp; (3) white rope fibres, such as Manila hemp, Sisal hemp, Mauritius hemp, and New Zealand Phormium; (4) brush and mat fibres, such as coir, piassava, kittool, and other palm fibres; (5) paper materials, such as esparto and wood pulp.

In the present lecture we shall confine our attention to the fibres of the Dicotyledons, embracing what are known as the higher and lower textiles, composed of (1) Seed-hairs, and (2) Bast fibres from the cortical layers of the green stems.

COTTON.

The chief, and indeed the only commercial fibre from seed-hairs, used in this country, is cotton. This consists of the delicate, tubular, hair-like cells clothing the seeds. The commercial value depends on the length and tenacity of these hairs or "the staple." The plants yielding cotton are amongst the most important in the vegetable kingdom. The use of cotton dates from prehistoric times. Sanscrit records carry it back at least 2,600 years, while in Peruvian sepulchres cotton cloth and seeds have been found. The value of the cotton manufacture of the United Kingdom exceeds £130,000,000 sterling.

The cotton plant belongs to the Mallow family. Three species are generally recognised.

1. The Tree Cotton (*Gossypium arboreum*).—A small tree or shrub with red flowers; not cultivated, usually, for cotton, but a variety is said to yield the "Nurma" cotton of India.

2. American Cotton (*G. barbadense*).—In this species the seeds are readily separable from the cotton or investing hairs. The produce is regarded as the most valuable of any, and is known as Barbados, Bourbon, Upland Georgia, and other short-stapled cottons. A variety (*G. maritimum*) yields Sea-island cotton, also Egyptian cotton, and a form of the latter, called Bahmia cotton. *G. acuminata* yields Peruvian or Brazilian cotton, sometimes called "kidney cotton" from the shape of the seeds. *G. barbadense* is the chief cotton plant of many parts of Africa, and the much prized "Dharwar" cotton of India. Of the world's supply of cotton the United States contribute about 56 per cent., though according to official statistics published in America it is estimated at not less than 70 per cent. The average number of acres under cultivation in cotton from 1880 to 1889 was 17,731,172; the average yield per acre was 168 pounds; while the average price per acre to the farmer was 8·8 cents. In the previous ten years, from 1870 to 1879, the average yield per acre was 191 pounds, while the

average price to the farmer per acre was 12·8 cents. Hence it may be inferred that the productive power of the cotton lands in the Southern United States has declined of late years, as also the profit to the farmer.

3. Asiatic Cotton (*G. herbaceum*).—The cotton is not so readily separable from the seeds. This and its varieties and hybrids, too numerous to mention, yield the chief cottons of India, such as Surat, Madras, and Bengal cottons. The plant is common in the Mediterranean region and every part of tropical Africa. It can be cultivated in colder countries than *G. barbadense*. A Chinese variety yields Nankin cotton, which is of a tawny colour. The total area in cultivation under cotton in British India in 1892-93 was nearly 9,000,000 acres. The largest areas were in Madras, Berar, Bombay, and the North-West Provinces. The highest exports during the last five years took place in 1889-90, when cotton to the value of 187,000,000 rupees was shipped from India. The export in 1892-93 was slightly less being of the value of 127,000,000 rupees. Besides cotton there was exported from India cotton seed in 1888-89 to the value of 301,577 rupees; in 1892-93 this had fallen to a value of 61,708 rupees.

As regards the industrial application of the various kinds of cotton, the following is a brief summary:—

Sea-island and Egyptian cottons are chiefly employed for fine muslins and laces; Brazilian and ordinary American, for cambrics and calicoes; inferior American and Indian, for fustian and heavy fabrics.

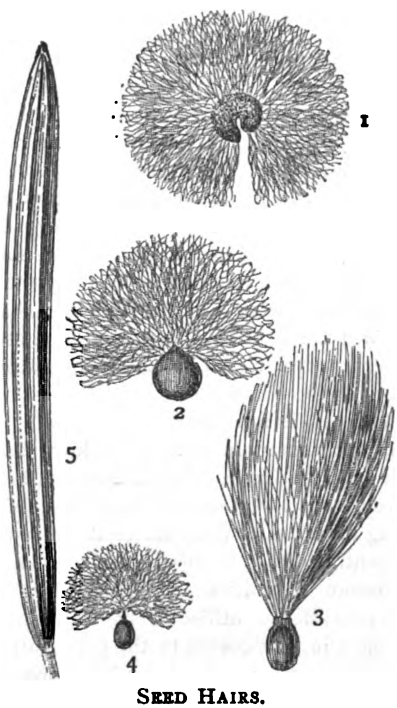
Further particulars of a useful character, on cotton: its cultivation, production, distribution, and consumption, may be obtained from the article, "Cotton," in "Chambers' Encyclopædia," iii., pp. 507-516. The present year is remarkable for the unusually low prices obtained for all kinds of cotton. Good, fair Bengal was selling, on the 25th March last, at $2\frac{1}{4}$d. per pound, good ordinary American, at $3\frac{1}{16}$d. per pound, while even the best Egyptian realised only $5\frac{9}{16}$d. per pound. As a result, many cotton-producing countries are reducing the area of cultivation, and directing attention to other products.

Kapok and Vegetable Silks.

Kapok is the Dutch name for the seed-hairs of the white silk-cotton tree of the East Indies (*Eriodendron anfractuosum*). The kapok of Java is regarded as the best. It is, however, too short in the staple, too smooth, and too soft to be spun into yarn. Its chief use is for stuffing pillows, mattresses, and sofas, where its lightness, insusceptibility to moths, softness, and elasticity render it superior to all but the best qualities of feathers, wool, and hair.

The floss from the red silk-cotton tree, *Bombax malabaricum*, known in India as *Semal*, is regarded as inferior to that obtained from the white silk-cotton tree. The principal market for kapok is Holland. In 1885 Java exported 600,269 kilos of kapok. In the West Indies both *Eriodendron anfractuosum* and *Bombax ceiba* are known as silk-cotton trees. It was recommended by the writer, in 1884, to export silk-cotton from Jamaica, where, at a low estimate, about 3,000 bales could be gathered every year.

FIG. 2.



SEED HAIRS.

1. *Cochlospermum Gossypium*. 2. Kapok (*Eriodendron anfractuosum*. 3. Madar (*Calotropis gigantea*). 4. Down tree (*Ochroma lagopus*). 5. Fruit of do. (reduced).

The Down-tree (*Ochroma lagopus*) of tropical America, especially Jamaica, belongs to the same natural order as the silk-cotton trees. The pod is long, and channelled longitudinally. The silken down which envelops the seeds is of a rich fawn colour, and very soft and elastic. It is used, locally, for stuffing beds. As the tree grows very fast, the down might be readily produced in large quantities,

Macfadyen says, "there is no doubt it could be made into cloth, and employed in hat-making."

The silky cotton of *Cochlospermum Gossypium*, sometimes known in India as the White Silk Cotton-tree, but entirely distinct from the tree above described under that name, has hitherto received little or no attention. The tree is common in the lower hills of India, and is often planted near temples. It has large, handsome, yellow flowers, and its pendulous, pear-shaped fruits ripen before the new leaves appear. The cotton is soft and silky, but very short. According to Dr. Watt it could be supplied at a much lower rate than the kapok, and has a resistance about it which prevents it from matting, like semal, when used in upholstery. This fibre has not yet been placed within reach of the European manufacturer. Its value is practically unknown.

Vegetable Silks.—Many plants belonging to different natural orders yield silky hairs, usually straight, forming a coma, or tuft at the apex of the seeds. Few of these have hitherto been investigated. The most familiar is that of the "madar" or "yercum" (*Calotropis gigantea*), or of the closely allied species (*C. procera*). The natives of India "regard the madar silk hairs as much cooler than semal, or red silk-cotton, and affirm that they have a soothing effect when used in pillows." As the plant will thrive in waste, and almost sterile and dry tracts of India, it would not be difficult to produce the silk hairs in any quantity. So far, however, it is nowhere cultivated. It is widely distributed in both the Old and New World tropics. In the West Indies it is known as French cotton, and the floss is used for making fans. Dr. Watt states that owing to the attention drawn to this fibre at the Colonial and Indian Exhibition, 1886, "it has been found possible to utilise it by mechanically drawing it in with cotton in the preparation of yarn." To overcome the difficulty of procuring a uniform supply it was proposed to attempt to cultivate the plant on a large scale. "It may thus be hoped that madar fibre may at last be viewed as an established new industry, that will greatly benefit the poor cultivators of a large tract of the less productive portions of India."

A noted vegetable silk is yielded by *Beaumontia grandiflora*, an extensive climber in East and North Bengal, with large showy flowers. It is cultivated in gardens for ornament. The seed-hairs are said to be the best yet known though least utilised. Specimens are in the Kew Museum. The fibre is very lustrous and purely white. It also possesses a remarkable degree of strength. The hairs are easily separated from the seeds, and are usually more than inch and a half long.

In the Argentine the silky hairs obtained from a plant, known locally as the "yachan" (*Chorisia insignis*), is used for a singular purpose by the Mataco Indians. These people make a netted cuirass from the fibre of a wild pineapple (*Bromelia serra*). This is padded before and behind with the silk hairs of the yachan. In order to make it impervious to the arrows of their enemies, the Indians roll themselves in water, until the fibre swells into a felted mass. The singular property possessed by this fibre could no doubt be utilised for other purposes.

II. BAST FIBRES.

The most familiar of bast fibres is the coarse reticulated bast of the lime tree, used for making Archangel mats. This is obtained from the inner bark. In other plants, such as flax and China grass, similar bast fibre is capable (as will be shown later) of being divided into fine, silky filaments, with strength, flexibility, and lustre almost equalling the finest silk.

The various bast fibres here enumerated are arranged in accordance with what is believed to be their intrinsic value.

Flax.

Flax, commercially, is the most important textile fibre next to cotton. It has been cultivated from remote antiquity. The plant (*Linum usitatissimum*) is an annual. The area of cultivation is world-wide, but chiefly in the temperate zone. The most suitable localities are belts of coast-land, subject to the moisture-laden winds from the sea. The value of the flax and tow imported into the United Kingdom, in 1893, was £1,104,851 sterling, chiefly from Russia. The other flax-producing countries are Germany, Austria, Italy, France, and Belgium. The Belgian flax is unequalled for quality. In the United Kingdom there are only 10,000 acres under flax. Large areas are cultivated in the United States, Canada, and British India, but almost entirely for seed purposes. Over 2,000,000 quarters of seed for oil and oil-cake purposes are annually imported into this country. A white linseed, in India, yields 45 per cent. of oil of a very light

colour. The fibre of flax is extracted solely by retting the stems with dew or in water. Then follow the "breaking" and "scutching," which consist in beating and shaking the broken flax in order to free it from loose and useless particles. All these are usually undertaken by the cultivator.

It is generally admitted that a new source of supply for flax, or at least a good substitute for it, is a desideratum in English manufacture. This may lead, eventually, to the commercial utilisation of China grass or ramie.

Good flax fibre consists of 80 per cent. of cellulose. The ultimate cells are 25-40 mm. long (about 1½ to 2 inches). In these two important characteristics flax is practically at the head of commercial fibres.

Remarks.—The bast layer in flax is in a continuous ring; sometimes two concentric fibrous zones are developed; the fibres with different features in each. The fibre bundles contain 5 to 10 cells or filaments, which are easily sub-divided. The cells, as already stated, are 25-40 mm. long. The normal have a small diameter, are thick walled and polygonal. The others are ovoid, with a large cavity resembling ramie.*

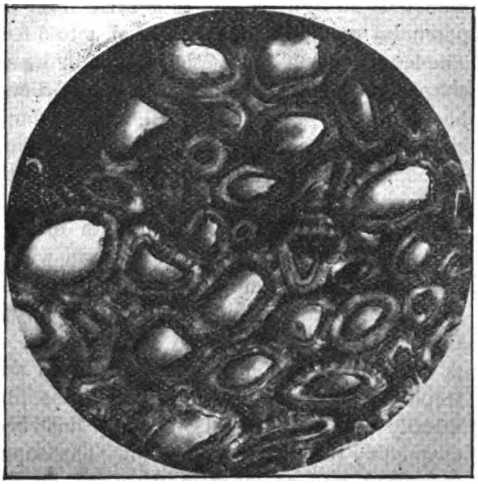
Hemp.

The term hemp is often used in a generic sense, and is applied to fibres derived from entirely different plants. Sunn-hemp is yielded by a species of *Crotalaria*, Manila hemp by a wild plaintain, Sisal hemp by an aloe (*Agave*), while "Chinese hemp" is applied indiscriminately to the fibre of an *Abutilon*, pineapple, China grass, as well as to the common hemp. The latter is the fibre of an annual (*Cannabis sativa*) closely allied to the hop-plant. Hemp is largely cultivated in Central and South Russia, Hungary, Germany, France, and Italy. Italian hemp is regarded as the best. In India hemp is cultivated solely for the narcotic resin yielded by the leaves and flowers. The dried leaves are known as "bang," while the dried flowers are called "gunjah." Both of these, as well as the gum-resin itself, are used for smoking. The characters of Indian hemp fibre, explanatory of the fact that it is useless for commercial purposes, are fully discussed by Vétillart, pp. 72-75. In temperate countries the fibre yielded by the male hemp plants is tougher and better than from the female plants. The male plants are gathered first, while the female plants are collected a month later. The extraction of hemp fibre is effected by means of retting, and breaking, and scutching, as in flax. Hemp ropes are very durable, and possess great strength and elasticity. In the Kew Museum is a portion of the cable of the *Royal George*, sunk at Spithead in 1782, and samples of paper made from it. Owing to the number of fibres, not real hemp, mixed together in the Customs' returns, it is impossible to give those for common hemp alone.

Madar Fibre.

Madar (*Calotropis gigantea*), already mentioned as yielding silky seed-hairs, also yields, from the inner bark of the young shoots and branches, a very valuable fibre. Dr. Watt speaks of it as one of the strongest and finest of vegetable fibres, and one of the most beautiful. By nitrating the fibre, under chemical treatment, a substance was produced by Cross and Bevan which could be scarcely distinguished from silk. The high expectations raised in regard to this fibre have not, so far, been realised; but, as the plant will grow in the poorest soils, and requires little cultivation, its double products of bast-fibre and floss deserve the fullest investigation.

Fig. 3.



Madar (*Calotropis gigantea*).*

Section through a portion of the bast region. The fibre cells are oval, with thick walls, loosely cohering together, and possessing characteristic markings. × 300.

* Unless otherwise stated the information in this and subsequent paragraphs under remarks is based on "Indian Fibres," by Messrs. Cross and Bevan.

* This, and similar illustrations, are from photo-micrographs by Mr. John Christie, F.R.M.S., of 72, Mark-lane, E.C. Both Mr. Christie's intimate knowledge of commercial fibres, and his large and varied collection of preparations relating to them have been very generously contributed to enhance the value of these lectures.

Remarks.—In the plant the fibre bundles are disposed in aggregates of 50 to 100. The cells are oval, loosely coherent. The bundles are usually in short lengths, 8-16 inches, owing to the nodes of the stem. The filaments, or cells, are 10 to 30 mm. long, ends tapering.

Rajmahal Hemp.

A large twining shrub (*Marsdenia tenacissima*), found in Northern India, is remarkable as yielding "one of the strongest and best fibres known in India." It is next to ramie in point of fineness and durability. If this plant could be cultivated for its fibre, it would become most valuable. Little, however, has been done in this direction since the days of Roxburgh. In point of intrinsic merit, Rajmahal hemp stands in the first rank of textile fibres. It is, however, quite unknown in commerce. Its merits are well set forth in Watt's "Dictionary of the Economic Products of India," V., pp. 188-190.

Remarks.—The fibre bundles are 10 to 15 inches long, with 10 to 30 cells in the bundle. The cells are 5 to 20 mm. in length.

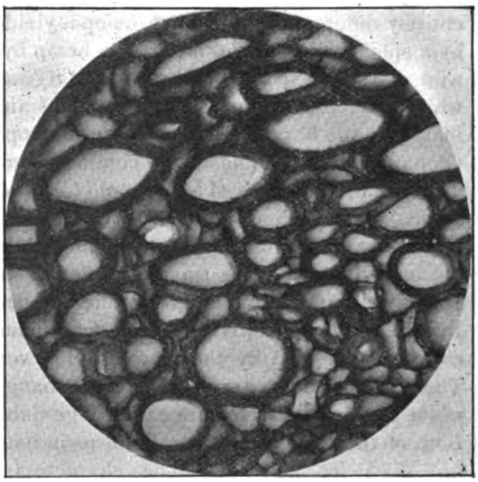
China Grass, Ramie, or Rhea.

China grass (*Bœhmeria nivea*).—This is a shrubby plant with the habit of the common nettle, but without stinging hairs. There are numerous straight shoots that arise from the perennial rootstalk to a height of 4 to 6 feet. The leaves are on long petioles, broadly heart-shaped, with serrated edges and white downy beneath. The seeds are small, and produced somewhat sparingly. This is the original China grass plant so long cultivated by the Chinese under the name of *Tchou Ma*. It grows moderately well in the south of England, and if the roots are covered in winter, they produce good crops of shoots that are fit to cut in September. In warmer countries China grass flourishes with great vigour. It is now distributed in most tropical and subtropical countries. The China grass fibre usually received in this country has been cleaned by the Chinese by hand. The supply is limited, and no large industry can be sustained by this hand-cleaned fibre alone. When carefully prepared and purified by chemical processes, China grass is pre-eminent amongst vegetable fibres for strength, fineness, and lustre. For more than fifty years it has been sought to cultivate the plant and to extract the fibre on a commercial scale. China grass is still, however, in the stage of expectancy. Many inventors claim that they have succeeded in solving the problems connected with it, but no one has yet so thoroughly established his claim as to induce extensive areas to be planted with China grass in any part of the world. Purely experimental plots are common everywhere.

There are two forms of this plant. One is the China grass mentioned above, a temperate, and the other ramie or rhea, a tropical plant, known as *Boehmeria nivea*, var. *tenacissima*. It would be well to preserve these distinctions in regard to the fibre also. The term ramie, or rhea, should only be applied to the variety *tenacissima*. This differs from the type by its more robust habit and larger leaves, which are green on both sides. This character easily distinguishes it from China grass, which has leaves white-felted beneath. The distinction here suggested is an important one. Ramie or rhea is a native of Assam and the Malay Islands. It thrives only in tropical countries, and it is useless to cultivate it elsewhere.

At Kew it has been found that while ramie or rhea (*B. nivea*, var. *tenacissima*) cannot be grown in the open air, the China grass (*B nivea*) remains in the ground all the winter, and furnishes a good crop of shoots, but only once in the year.

Fig. 4.



China Grass (*Boehmeria nivea*).

Transverse section × 150. The fibre cells are round or oval, with moderately thick walls and large cavities.

The value of the ramie, or rhea fibre, as compared with China grass, has not been carefully and fully investigated. Ramie from India has, however, not proved so valuable, so far, as the China grass. In the large mass of

literature on China grass there is considerable confusion between it and ramie or rhea, and the results in consequence lose their value.

Remarks.—In the plant the bast is a continuous ring, with the cells in loose contact. In a cross-section the latter appear ovoid to polygonal, with a large cavity; they are, however, very variable. The mean diameter is greater than in flax. The fibre bundles are usually three in number, frequently single. The cells are of exceptional length, 40 to 200 mm. (1½ to 10 inches). This is greatly in excess of any known fibre.

Cultivation.—Our knowledge of the cultivation of China grass is derived from the Chinese. It can be propagated either by seed or offshoots. Where seed is used, nursery beds carefully prepared, supplied with rich soil, and regularly watered are essential. Care should be taken to mix the fine small seeds of the China grass with soil, and sow lightly on the surface of the ground. The plants raised in these beds may afterwards be transplanted, and put out at distances varying from 1½ to 2 feet apart, according to the nature of the soil; the better the soil the further apart the plants; and, conversely, the poorer the soil the closer the plants. Clay soils appear to be quite unfit for the cultivation of China grass, and hence these, as also very light, poor, gravelly soils should be avoided. The latter may, of course, be improved by abundant and regular supplies of manure, but the cost of cultivating China grass on such soils would render it prohibitive as an article of export.

When off-shoots or suckers can be obtained, they are to be preferred to seeds, as being more expeditious, and yielding better results. When off-shoots or suckers cannot be obtained in sufficient numbers, young plants may be obtained by "layering" the taller stems, that is, bending them down (without breaking) close to the ground, and covering the joints with soil. From every ripe joint plants will be produced.

The burden of the treatment of the China grass, in all its stages, by the Chinese, is the plentiful use of manure and water. Unless the soil is naturally rich and moist, the cultivators of China grass must be prepared to supply their plants largely with manure, and keep them in a vigorous and continuous state of growth.

Cutting the Stems.—The shoots are fit to cut when the bark is of a brown colour for about six inches from the roots. In the process of cutting, the young shoots springing from the rootstalk should not be injured, as they would form the succeeding crop. When once the China grass plants are established, the stems are produced more abundantly with age, and also grow much faster. Where too thick they should be carefully thinned so as to promote the growth of large healthy unbranched stems. The duration of life of the root depends on the strength and character of the soil, the relative quantity of manure supplied, the amount of moisture present, as well as on the general cultural treatment received by it. There is no reason to doubt that where favourable conditions exist a plantation of China grass will last for many years (ten or twelve), and prove very productive.

The above remarks on the cultivation and cutting of China grass apply equally well to ramie or rhea.

Yield.—From a small patch of China grass (*Boehmeria nivea*), now five years old, growing in the open air at Kew, it has been found that 4 square yards yield 100 stems. The weight of these, without leaves, was 24 lbs. This gives a yield at the rate of 29,000 lbs. per acre. In Algiers, Hardy found that an acre yielded 27,000 lbs. of similar stems without leaves. De Mas, at Padua, found that Ramie (*Boehmeria tenacissima*) yielded in the second year stems, without leaves, at the rate of 26,300 lbs. per acre; in the third year two crops yielded at the rate of 32,360 lbs. per acre. The weight of raw fibre (ribbons ?) per acre obtained by De Mas from 32,000 of green stalks, without leaves, was 1,280 lbs. Favier gives somewhat similar results. His actual yield was 1,285 lbs. per acre. In California, Hilyard gives it as 1,935 lbs. per acre. It is probable that the yield of clean ribbons per acre on a large area, with two or three cuttings, will average about 900 to 1,000 lbs. per acre. Mr. Charles Richards Dodge, of the United States Department of Agriculture, is of opinion "that two cuttings of second year's growth ramie, when properly cultivated, will produce 20 tons of green stalks with their leaves." Further, "as each ton of green stalks, with leaves, will yield 46½ lbs. of clean dry ribbons or raw fibre, giving 25 lbs. of degummed fibre," we have, therefore, a return per acre from two cuttings equal to 930 lbs. of clean ribbons and 500 lbs. of degummed fibre or filasse. No returns of the actual fibre have, however, been made continuously on a sufficiently large scale to justify absolute confidence in them.

At Wenchow, China, it has been found that an acre, in one cutting, yields 80,000 stems, giving 312½ lbs. of fibre. This would probably be the ordinary ungummed China grass as received in this country. Three crops would therefore yield at the rate of 937½ lbs. per acre.

Extracting the Fibre.—In January, 1870, the Government of India was so impressed with the value of ramie or rhea as a commercial fibre that it offered a prize of £5,000 for a machine or process that would produce "a ton of fibre of a quality which should average in value not less than £50 in the English market," at a total cost (all processes of manufacture and allowance for wear and tear included) of not more than £15 per ton. A trial of machinery took place at Saharunpur in August, 1872. The prize was not awarded. A donation was however given to one machine, which produced an inferior fibre worth but £18 per ton, and fit only for cordage. In 1877 the offer of a prize was renewed and a further trial took place in September, 1879. The results were equally inconclusive. This offer of a prize by the Government of India was definitely withdrawn in 1881. Since 1881 numerous efforts have been made to devise means for extracting the fibre. A process that had some success was the Favier-Fremy process, in which the stalks were steamed and the ribbons or strips were afterwards cleaned by chemical means. In 1888 there took place the first of the International competitions held in Paris. The results are given in the "Kew Bulletin," 1888, pp. 273-280. Two machines received a gratuity only. The trials were renewed in connection with the Paris Exposition Universelle in 1889. A report of these is given in the "Kew Bulletin," 1889, pp. 258-278. First prizes were awarded to Mons. P. A. Favier, Société de la Ramie Française, for a mechanical process with rollers, and to Mons. Norbert de Landtsheer, for a machine with a drum and beaters. The former cleaned at the rate of 443 lbs. and the latter at the rate of 575 lbs. of dry ribbons per day of ten hours, from green stems without leaves. A second prize was awarded to MM. Ch. Crozat de Fleury et A. Moriceau, for a process for steaming the green stems in the fields, and peeling the ribbons by hand. The Favier mechanical process has since been used to extract fibre in France and Spain on a moderately large scale. It is, however, not available for general use, as the inventor prefers to keep it in his own hands.

In 1891, a third series of trials was held at Paris under the auspices of la Société des Agriculture de France. The results were promising, but no practical advance was made on those reported for 1889. In America trials were held at New Orleans under the auspices of the Department of Agriculture, Washington, in 1892 ("Kew Bulletin," 1892, pp. 304-306). These were renewed in October, 1894, and a detailed account is given in the "Bulletin" of the Experimental Stations of Lousiana, No. 32, 1895. "Two machines were entered for trial, one by the Textile Syndicate, 72, Finsbury-pavement, London, for green decortication, and the other by Samuel B. Allison, of New Orleans, for dry decortication." The committee stated: "We report great progress in ramie machines since our last test (in 1892), but neither of the machines are yet ready for successful operation on a small scale by farmers and planters." They added "the outlook is promising."

There are several machines and processes now under experiment in this country, but no public trial has been attempted owing, probably, to the absence of sufficient material to operate upon. It is obvious that such trials can only be properly carried on where there are large areas planted, and where stems are available for continuous working.

Numerous articles have lately appeared respecting a revival of interest in ramie. There is no doubt a large amount of money is being spent in the endeavour to solve the ramie question. Quite recently it was claimed that "the treatment of ramie can now be carried on upon lines that will enable it to take its place among the other textiles . . . . inferior only to silk in point of 'number' or fineness."

What may be regarded as a distinct advance has been made in the treatment of raw ramie ribbons by the Forbes process, now under trial in this country. The filasse produced by this process, forwarded to the Kew Museum, is of exceptional quality. From the Boyle Fibre Syndicate there has been received, for the first time, a complete set of samples of ramie goods manufactured in this country. The yarn was spun at the Long Eaton Mills in Derbyshire. These are quite equal to the best French manufacture. A very complete series of these and similar articles may be seen in the Kew Museum I., Ground Floor, Case 103.

In order to understand the special character of the China grass, or ramie industry, it is desirable to enumerate the different stages connected with it. In the first place, we have the mere business of cultivating the plant, and of producing stems containing the fibre in

the best possible condition. This is purely the work of the planter. Secondly, we have the process or processes necessary to separate the fibre from the stems in the form of ribbons and filasse. It is necessary, for many reasons, that this should be done, either by the planter on the spot, or by a central factory close at hand. Thirdly, we have the purely technical and manufacturing process, in which the filasse is taken up by the spinners, and utilised in the same manner as cotton, flax, and silk are utilised for the purpose of being woven into fabrics.

It may be mentioned that the cultivation of the plants presents no difficulty. They will grow rapidly enough, and, if highly cultivated, will produce two or three, or possibly more, cuttings each year. The chief difficulty is in devising means for extracting the fibre from the stems cheaply and expeditiously. The next stage for treating the ribbons chemically, and preparing a white "filasse," appears to be much more advanced.

Other Nettle Fibres.

Besides China grass and ramie there are many other nettle fibres obtainable from Indian plants that are deserving of notice. It is probable that some of these may be even better than ramie, or at least more readily available for cultivation in certain parts of India. A brief enumeration of the plants yielding these nettle fibres is all that is possible within the limits of this lecture.

Tashiari (*Debregeasia hypoleuca*).—A large shrub forming dense undergrowths in the Himalaya. The branches and leaves are clothed with a snow-white wool. The fibre is extracted by boiling the stalks in water and wood-ashes. The fibre is afterwards washed, sprinkled with the flour of *Paspalum scrobiculatum*, and left to dry. It is then ready for spinning. In some parts of India this fibre, on account of its strength, is used for bow-strings.

Nilgiri Nettle (*Girardina heterophylla*).—A stout tufted herb, rising to 6 feet in height. All parts are covered with stinging hairs. "The bark abounds in fine, white, glossy, silk-like strong fibres" (Roxburgh). The stinging hairs are an obstacle to the utilisation of this fibre, but it is undoubtedly of great intrinsic value.

Poi (*Maoutia Puya*).—A shrubby nettle with leaves white beneath. Dr. Watt reports on this plant:—"Probably more easily cultivated than rhea, while the fibre would be found quite as serviceable."

Ban-rhea (*Villebrunea integrifolia*).—This "wild rhea" of Assam is said to yield a fibre stronger than either China grass or rhea. The plant is cultivated by the native tribes in north-east India, and from it they obtain "a fine fibre, admirably adapted for fishing lines and nets, and remarkable for its power of resisting moisture." It has been recommended to the Government of India to cultivate this plant, and investigate its merits side by side with China grass and rhea.

Ban-Surat (*Laportea crenulata*).—This is a wild nettle of India and Ceylon. It is an evergreen shrub growing in the interior hills, and clothed with stinging hairs. The stems yield a strong useful fibre, suitable for ropes and paper-making. Good specimens of the fibre are in the Kew Museum. A sample from Ceylon is labelled "Maoosa" fibre.

Besides these Indian nettles, a few plants, closely allied to them, have come into prominence in other parts of the world:—

Urera Fibre (*Urera tenax*).—A large shrubby or tree-like nettle of Natal, where the bark is highly prized by the natives for the sake of the fibre yielded by it. The fibre is made into thread or cord, and closely resembles China grass, but is rather more brittle, and not so lustrous. This is a comparatively new fibre, first described in the "Kew Bulletin," 1888, pp. 84-85, with a plate.

Mamaki (*Pipturus albidus*).—A shrubby nettle of the Pacific islands, especially the Hawaii archipelago. The bark is used for the manufacture of native cloth (similar to that prepared from the paper mulberry—*Broussonetia papyrifera*). Some fine specimens of fibre and cloth are in the Kew Museum.

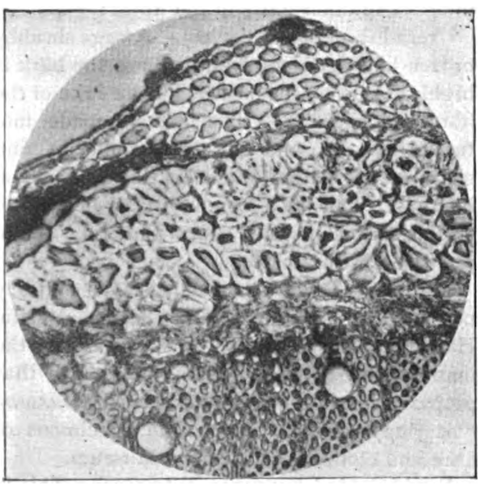
Rere (*Cypholobus macrocephalus*).—This is another shrubby nettle from the Pacific islands, but more widely distributed than the last. The fibre from the bark is made into white fine mats, which in Samoa are "a medium of exchange and a standard of wealth" amongst the native chiefs.

Sunn-hemp and Sida Fibre.

Sunn-hemp (*Crotalaria juncea*). — An annual shrub belonging to the Leguminous order, 6 to 10 feet high, with bright yellow flowers resembling those of the common broom. It is grown in western and southern India, over an area of 150,000 acres, for the sake of its fibre. This is known as Sunn-hemp, Bombay hemp, Madras hemp, and Jubalpur hemp. The stems after being cut are steeped in water until the bark is loosened. The latter is then taken in handfuls and beaten

on the surface of the water until the fibrous part is separated and thoroughly washed. The fibre after being dried is cleaned and combed. Roxburgh and Royle showed beyond all doubt that Sunn-hemp was superior to jute, and this fact has since been confirmed. Dr. Watt states as his opinion, after carefully weighing the relative merits of Sunn-hemp and jute, "it is impossible to urge too strongly the claims of this much neglected fibre." London brokers state that the only difficulty in pushing the trade in Sunn-hemp is the inability to procure a uniform and large enough supply. If encouragement were given to the industry in Southern India it is confidently anticipated that the foundation would soon be laid for a textile industry that would bear creditable comparison with the jute trade of Bengal.

FIG. 5.



SUNN-HEMP (*Crotalaria juncea*).

Section through stem. The uppermost tissue is the cortical parenchyma; next below is the bast region with fibre cells; lastly, comes the lignified or woody tissue, with two large pitted vessels. Between the bast region and the wood is the cambium region. × 150.

Remarks.—The fibre bundles consist of 20 to 50 cells, not easily divided. Each cell is 3 to 5 mm. long with the ends tapering abruptly; polygonal in transverse section with a small cavity. The wall of the cell shows well marked concentric rings.

Sida hemp (*Sida rhombifolia*).—A very variable plant, widely distributed in tropical countries, with yellow or white flowers. It yields an excellent fibre, said to be better than jute, but, unlike jute, capable of cultivation over immense tracts of country. Sida fibre, from Queensland, exhibited at the Colonial and Indian Exhibition of 1886, gave great promise. Its superiority to jute was shown in the "uniformity, firmness, and divisibility of the fibre bundles, and in the softness and colour of the raw fibre; it had also great capacity for bleaching." In regard to its future in India, Dr. Watt states, "no fibre of modern times affords better hopes of success than Sida."

Remarks.—The fibre bundles are similar to jute in all structural points. The filament is 1·5 to 2 mm. long, hardly distinguishable from jute.

JUTE.

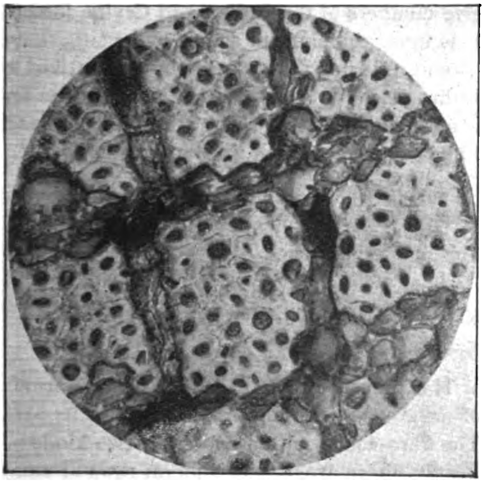
Jute (*Corchorus capsularis*).—The jute trade of India is of the annual value of £10,000,000 sterling. There are about 2,000,000 acres under cultivation. The plants yielding jute are of two species. The one now under consideration is an annual, about 2 to 5 feet high. The base of the leaves is prolonged into two curious tail-like appendages. The fruit is a globose capsule, not beaked. The seed is sown broadcast in March to June and the crop is gathered to the end of September. It therefore occupies the ground only for about three to four months. When the stems are ripe they are cut down and steeped in water for several days, until the bark is rendered soft and loose. The fibre is taken off by hand, and after being thoroughly washed it is hung up in the sun to dry. The preparation is, therefore, very simple, and no machinery of any kind is necessary. The best qualities of jute are of a pale, clear colour, with a silky lustre, easily spun and comparatively strong. There are numerous commercial sorts varying in colour, degree of fineness, and in lustre. Those of bad colour are chiefly used for gunny bags. To lessen the harsh and brittle character of jute it is subjected to a crushing process with oil and water which softens the fibre and prepares it for the spinning processes. Dundee has long held a supreme position as the seat of jute manufacture, but many factories have, of late years, been started in India. The class of goods manufactured is not, however, the same.

The chief defects of jute are—(1) The fibre will not bleach readily; and (2) fabrics manufactured from it are apt to rot, when exposed to damp. It is, however, extensively used in the manufacture of gunny bags, gunny cloths, rope, twine, carpets, rugs, and printed tapestry.

Remarks.—Jute fibre consists of the fibre bundles, cleaned by retting and washing.

Each bundle consists of 6 to 20 cells. The latter are firmly coherent in the bundle. The cells are of the normal fusiform type, from 1·5 to 3 mm. long. In section they are thick-walled and polygonal.

FIG. 6.



JUTE (*Corchorus capsularis*).

Section, highly magnified, through a portion of the bast region, showing the rectangular form of the fibre bundle, divided by plates (shown dark above) of loose cellular tissue. × 300.

Calcutta Jute (*Corchorus olitorius*).—The plant yielding the jute chiefly produced in the neighbourhood of Calcutta is very similar to the common jute; but the fruit is horn-like, instead of globular, and possessed of a distinct beak. It is cultivated in many parts of the world as a vegetable, under the name of the "Jew's mallow." As a fibre plant it is regarded as of less value than the previous species. The methods adopted for its cultivation and the extraction of the fibre are identical with those of common jute.

Chinese Jute is in some cases derived from the same plant as Indian jute (*Corchorus*); but some fibres exported from China as jute are yielded by very different plants. It appears that "jute" pays an export duty of 2 mace per picul, while "hemp" is charged 3½ mace per picul. There is, therefore, an incentive to pass all fibres as jute instead of under their proper names. American jute is sometimes an *Abutilon* fibre, and sometimes identical with Indian jute (see *Abutilon Avicennæ*). A West African jute from Lagos is described in the "Kew Bulletin," 1819, p. 15. This is known locally as Bolobolo fibre. It is yielded by *Honckenya ficifolia*. In 1889 the fibre was valued at £16 to £17 per ton.

HIBISCUS FIBRES.

Numerous species of *Hibiscus*, or mallows, are known to yield very serviceable fibres. The following are a few of the most notable:—

Deccan Hemp (*Hibiscus cannabinus*).—This is also known as Kanaff and Ambari hemp. The plant is a slender herb; the flowers are yellow, with a crimson centre. The fibre is said to be strong and durable, but so far is not known in commerce. Latterly it came into notice under the name of Kanaff, in the Caucasus ("Kew Bulletin," 1891, pp. 204-206).

Okra (*Hibiscus esculentus*).—An annual herb, yielding a fruit used as a table vegetable known as okra, okro, or gombo. The stem contains a useful fibre with great strength and lustre; it is adapted for making ropes, twine, and sacking.

Rozelle, or Red Sorelle (*Hibiscus Sabdariffa*).—An annual shrub. The succulent calyx is edible, and is used for making cooling drinks. The fibre is strong and silky, and is known as Rozelle hemp.

Maholtine (*Abutilon periplocifolium*).—A shrubby plant with stems 8 to 10 feet long, common in tropical America, but also found in West Africa and the Nile Valley. This is recommended as yielding a jute fibre of considerable merit. Specimens sent to Kew from Trinidad, in 1889, were valued at £17 per ton. An account of the Maholtine as a new fibre plant is given by Mr. J. H. Hart, F.L.S., in the "Agricultural Record," (Trinidad), vol. i., p. 217.

Ban-ochra (*Urena lobata*).—A very variable plant, widely distributed in the tropics. In India, the easily extractable fibre is considered suitable for the manufacture of sacking and twine, and a fair substitute for flax. The "Toja" fibre of West Africa is yielded by this plant. Samples sent to Kew, in 1889, were valued at £17 to £18 per ton.

Remarks.—The fibre bundles are indistinguishable from characteristic *Hibiscus* fibre. The filaments or cells are short, scarcely more than 1·5 to 2 mm. long.

Indian Mallow Hemp (*Abutilon Avicennæ.*)—This is also known as China jute and American jute. The plant is a shrubby mallow, with yellow flowers. The fibre is said to be superior to Indian jute. An account of the plant, giving particulars respecting the cultivation and extraction of the fibre in China, is given in the "Kew Bulletin," 1891, pp. 255-256.

Of plants belonging to the Leguminous order we have so far only mentioned the Sunn-

hemp (*Crotalaria juncea*). The following also produce useful fibre.

Dhunchi Hemp (*Sesbania aculeata*).—This is of interest from the fact that the plant will grow in swampy situations. The stems are produced to the height of several feet. Royle states: "The bark yields a very excellent fibre for common cord and twine purposes, much superior in strength and durability to jute." From the pith of the twigs very singular and ornamental mats are also made in Assam.

Ko Hemp (*Pueraria thunbergiana*).—A trailing vine, producing flowers like a Wistaria, long known in China and Japan, yields a very interesting fibre. This is obtained from the succulent green stems, and is used, but less than formerly, for summer clothing. It is said to be more durable than China grass cloth.

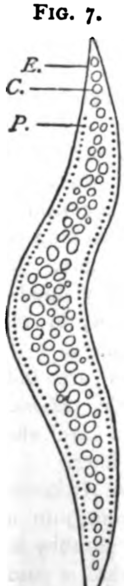
Malu Fibre (*Bauhinia Vahlii*).—The plant yielding Malu fibre is one of the most extensive climbers of the Indian and Ceylon forests. It is most abundant in warm, moist situations. The fibre is universally used by the natives of India. Dr. Watt states: "It is one of the few vegetable fibres that will stand to be dyed, bleached, and worked up along with wool."

LECTURE II.—DELIVERED MARCH 25, 1895.

III. ENDOGENOUS FIBRES.

The fibres of Endogens or Monocotyledonous plants are found isolated in the stems and leaves. They do not form a continuous ring as in the bast fibres of Dicotyledonous plants. They occur in definite bundles, called fibro-vascular bundles, distributed in the cellular tissue, and usually enclosed in a bundle sheath. All the fibres proposed to be dealt with in this lecture are derived from the leaves of tropical endogenous plants. In fact, they may very appropriately be called leaf fibres, as opposed to the stem or bast fibres of exogenous plants treated in the last lecture. The mode of occurrence of the leaf fibres is very similar in all cases. A typical example is found in the valuable fibre obtained from the leaves of species of *Agave*. This fibre is known in commerce as Sisal hemp. The leaves in this case are sword-shaped, somewhat fleshy, firm in texture, and terminating in a sharp spine. They are arranged in a rosette, with about 30 or 40 leaves in each rosette. The most familiar example of this is the common American Aloe (*Agave*).

FIG. 7.

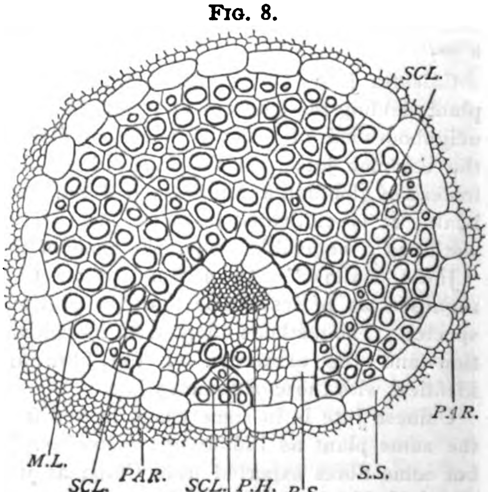


SISAL HEMP (*Agave rigida*, var. *sisalana*).

Transverse section through the middle of the leaf. The right hand side represents the upper surface; *E*, epidermis; *P*, peripheral row of bundles; *C*, central row of bundles.

The preceding figure gives the appearance of an Agave leaf, cut transversely to its axis. The fibro-vascular bundles are of two kinds:—Firstly, there are the peripheral rows of small bundles, occurring immediately under the epidermis, on both surfaces of the leaf. These

FIG. 8.



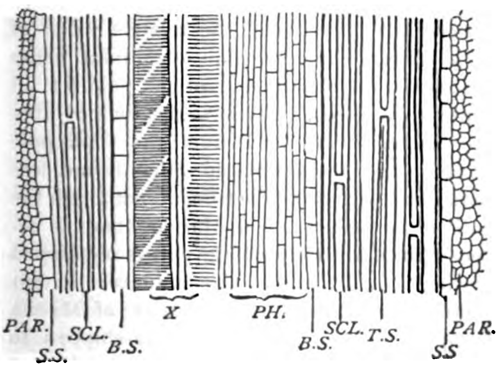
SISAL HEMP (*Agave rigida* var. *sisalana*).

Transverse section through a fibro-vascular bundle embedded in (*PAR*) the cellular parenchyma. *S.S.* starch layer, forming a ring round the sclerenchyma (*SCL.*), with the fibre cells closely packed together. *M.L.* middle lamella. *B.S.*, bundle sheath. *X.*, xylem, or wood cells. *P.H*, phloëm, or bast cells. × 300.

two rows extend from the centre outwards, but they terminate abruptly before they reach the margin. Secondly, there are the central bundles of fibre, one row of which reaches quite to the margin of the leaf. These central

bundles vary considerably in size, those near the centre being generally largest. At the centre the rows are two to four deep. The space between the bundles is occupied by small-celled tissue, called the parenchyma. This is merely a packing material, and is useless for fibre purposes. To find the fibre material, and its structure relatively to other tissues, we must examine one of the fibro-vascular bundles from the centre of the leaf.

FIG. 9.*



SISAL HEMP (*Agave rigida*, var. *sisalana*).

Longitudinal section of a fibro-vascular bundle:—*PAR*, parenchyma; *S.S.*, starch-layer; *SCL.*, sclerenchyma; *B.S.*, bundle sheath; *X*, xylem; *PH.*, phloëm; *T.S.*, transverse septum (termination of fibre cells). × 300.

The whole bundle is surrounded by the small-celled parenchyma, only slighly shown in the above figure. Next come the large, thin-walled cells of the starch layer, completely surrounding the bundle. Inside this is the large mass of tissue called the sclerenchyma,† somewhat crescent-shaped, and embracing within its two horns the vascular bundle. The crescent-shaped mass is made up of a number of thick-walled cells with a central cavity. These cells form the fibre of commerce. The vascular bundle consists of two parts, the wood and the bast. In endogens the bast is useless for fibre purposes, hence it is incorrect to speak of the bast fibres of Monocotyledonous plants. To extract the fibre cells in this case it is necessary in the first instance to get rid of the small-celled parenchyma, and also of the vascular bundle. The fibre bundle would then consist (in section) of a crescent-shaped body made up of thick-walled cells only. These cells may number from 50 to 200 in each bundle. They are closely compacted by pressure, and their walls have grown so thick, that the internal cavity, in some cases, is almost blocked up. Each cell is really separated from its neighbour by a thin partition called the middle lamella.

The further structure of a fibro-vascular bundle is shown in a longitudinal section. On each side, as before, is the parenchyma, next the starch layer, and then the fibre cells or sclerenchyma. In the longitudinal section above *SCL.* is seen the somewhat abrupt termination of one or two of those fibre-cells (known as the transverse septum). Next to the sclerenchyma is the bundle sheath, *B.S.*, and then come the wood cells, *X*. These are long, wide, somewhat thick-walled, and characterised by peculiar ladder-like markings. Next to the wood cells comes the bast or phloëm. The cells are mostly short, very delicate, and thin-walled. It is evident that they are useless for fibre purposes. The fibre cells, it is noticed, are very long; they have a narrow internal cavity, and lastly, they have thick cell-walls. All these points add to their value as a fibre material. They are the essential parts sought for in fibre plants, and, as will be shown later, they constitute in all cases the fibres of commerce.

MANILA HEMP.

The plant yielding Manila Hemp (*Musa textilis*) is a wild plantain, native of the Philippine Islands, where several varieties are now cultivated for the sake of the fibre. The stem, made up of the leaf-sheaths, rises to the height of 12 to 20 feet, with leaves similar to the common plantain, but narrower. The fruit is hard and dry, not edible.

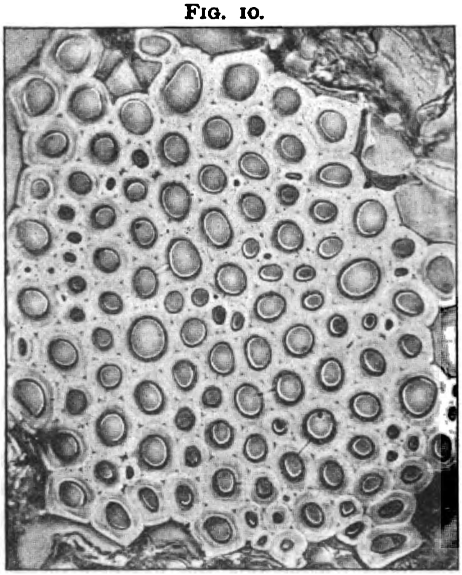
Cultivation.—The plant is propagated by means of suckers thrown out at the base of the parent stem. Plantations are established in fresh clearings on low hills and under the shade of trees, left standing at 60 feet apart. The cost of establishing plantations is about £5 to £8 per acre, not including the cost of the land. After this the yearly expense of weeding and maintaining the plantation in full bearing is at the rate of 30s. to 35s. per acre. The first crop is reaped at the end of eighteen months or two years after planting. The yield during the third and fourth years is at the rate of 400 lbs. to 700 lbs. of dry fibre per acre. The cleaning is done entirely by hand. No machine has yet been invented that will extract the fibre so efficiently and cheaply. A labourer, working under pressure, will clean about 20 lbs. of hemp per day. Usually two men work together, one cutting

* Figs. 7, 8, and 9 are adapted from a paper by Mr. C. H. Nicholls, B.A., in the *Journal of the Institute of Jamaica*, vol. i., p. 154.

† From the Greek *skleros*, stiff, hard.

down the soft stems and splitting them, while the other cleans the fibre. In many cases the workers are paid one-half of the price of the fibre cleaned per day. At the current value of hemp in 1879, one labourer's earnings were estimated at 7½d. to 8d. per day. From these particulars it may be gathered that the Manila hemp industry in the Philippines is fostered by very exceptional circumstances. The plant is native of the country. It is cultivated on virgin soil, of which, in that part of the world, there is a considerable extent; and, in addition, the labour supply is both cheap and abundant. It is important to bear these facts in mind in starting the cultivation of any fibre that is likely to come into competition with Manila hemp. Even in the Philippines there are districts in the western and northern parts, with a drier climate, where the plants will not grow. Hence it is useless to attempt to establish a Manila hemp industry in any country where the soil is not rich, and where there is not an abundant rainfall well distributed throughout the year.

FIG. 10.



MANILA HEMP (*Musa textilis*).

Transverse section through a fibro-vascular bundle from the leaf sheath forming the so-called stem of the Manila hemp plant. The fibre cells are variable in diameter, with the cavity circular or oval. The divisions between the individual cells are more clearly shown in Fig. 8. × 300.

Fibre in Commerce.—Manila hemp is "the chiefest and best" of white cordage fibres. After it is extracted by hand it is thoroughly dried in the sun and packed by hydraulic pressure in bales ready for shipment. Hemp not properly dried, or exposed to rain, becomes discoloured and loses strength. It is characteristic of Manila hemp that it readily absorbs moisture and in an ordinary dry condition it contains 12 per cent. of "water of condition." The various qualities of Manila hemp in March, 1895, were selling per ton as follows:—Lupiz, £30 to £50; Quilot, £28 to £40; prime roping, £21 to £25; fair current, £17 to £18 10s.; seconds, £16; good brown, £14 10s.; common do., £13 10s. At this time Sisal hemp was selling per ton at £14; Mauritius hemp at £21 to £24; New Zealand Phormium at £12 to £14. The prices above quoted afford a very fair criterion of the relative value of these fibres. The position of Manila hemp practically determines the prices paid for all white rope fibres. About 50,000 tons of fibre are annually exported from the Philippine Islands, and the estimated value is not less than about £2,500,000 sterling. Although the bulk of the shipments of Manila hemp is received in this country a large part is re-shipped to the United States. For instance, in 1891 there were received 448,000 bales of Manila hemp. Of these 175,919 were re-shipped to America. The total receipts in the United States during 1891 (direct and indirect) were 316,677 bales. If we include Manila and Sisal hemp the consumption of these fibres in the United States is more than twice as much as in the United Kingdom.

Economic Uses.—Manila hemp is largely used as a material for white ropes for rigging and other purposes, It is also largely used for binders for reaping machines. Old Manila ropes make an excellent paper material. The manufactured articles made of Manila hemp in the Kew Museum consist of mats, cords, hats, plaited work, and lace handkerchiefs. One of the latest applications of this fibre is in the manufacture of lace and materials for ladies' hats and bonnets.

A successful attempt to establish a Manila hemp industry in British North Borneo has lately been reported. Owing to the heavy taxes in the Philippines it is claimed that North Borneo can export its fibre at a lower cost than the Philippines.

PLANTAIN AND BANANA FIBRES.

Besides Manila hemp, produced by *Musa textilis*, other species produce fibre useful for cordage purposes, for mats, and for making coarse paper. The plantain, in Jamaica (*Musa sapientum*, var. *paradisiaca*), produces a white, glossy fibre at the rate of 1·81 per cent. of the gross weight. The price of the best plantain and banana fibres is, however,

seldom above £12 per ton, and they would only fetch this price when there is a high demand for white-rope fibres, and a short supply of Manila and Sisal hemps. In spite of this, it is worthy of consideration, whether the immense number of banana stems cut down every year in the West Indies (estimated at 50,000,000) could not be utilised for their fibre. It is evidently not sufficiently good to compete with first-class rope fibre, but it might possibly be used for making coarse paper, as a packing material, or even for the manufacture of *papier maché*. The Abyssinian banana, *Musa Ensete*, yields a somewhat weak and dull-looking fibre. *Musa Bajoo* is grown in Southern Japan for its fibre, which is woven into cloth of an exceedingly durable character. *Musa sumatrana*, forming an impenetrable jungle in the Malay Peninsula may eventually prove a useful fibre plant. A banana, native of the Solomon Islands, yields fibre which is woven into ornamental garments, bags, and sleeping mats.

PINE-APPLE FIBRE.

The common pine-apple (*Ananas sativus*) has a rosette of 30 to 50 narrow, strap-shaped leaves, from 3 to 5 feet long. These contain an abundance of fibre which, though somewhat difficult to extract, is possessed of great merit. It is finer and stronger than that yielded by almost any other plant except China grass. In the East Indies it is manufactured into a beautiful fabric known as "piña" cloth. In the Straits Settlements, Sierra Leone, and some other localities in the Old World, this tropical American plant has become thoroughly naturalised. The leaves in these semi-wild plants are more highly developed than in plants cultivated for the fruit, and hence are better suited for fibre purposes. In the Philippines it is also customary to pluck the fruit before it matures; this is said to cause a considerable extra development of the leaves.

Pine-apple plants are grown in every tropical country, and their cultural treatment is well known. They are easily propagated by means of offsets from the base. The leaves are fully developed in about 12 to 18 months, and each plant could yield at least 10 to 20 leaves every year. For piña cloth the fibre is extracted by scraping by hand, then washed and laid out to bleach in the sun. The steeping, washing, and drying are repeated until the fibres are considered to be properly bleached. The fibre bundles are very fine, transparent, strong, and supple. The ultimate cells are from 2 to 5 mm. long, fine, uniform in diameter throughout, solid and glossy.

A sample of pine-apple fibre of excellent and extraordinary length (6 feet), grown at Malacca, was brought to this country by Mr. Derry in 1893. It was stated, in the "Kew Bulletin," 1893, p. 368, that one manufacturer was hopeful of using 1,000 tons a year or more of this fibre at the price of £30 per ton, delivered in London. "Pine-apple hemp" is a regular article of export from Formosa to Swatow, where it is made into fine "grass cloth," esteemed for its coolness as a summer wear.

CARAGUATÁ FIBRE.

Caraguatá (*Bromelia argentina*).—The best fibre of Paraguay is "Caraguatá ibera." It is described as long and silky. There is frequent mention of it in works of travel, and fine specimens were shown in the Paraguay Court at the Exposition Universelle, held at Paris in 1889. Specimens of the plant, abundant in a wild state, were received at Kew in 1890, and it was found to be a new species of *Bromeliaceæ* allied to the pine-apple, which it resembles both in habit and character of the leaves. In a report furnished to the Foreign-office by Mr. Arthur Herbert (No. 1,006, 1892), it is stated "the *ibera* is a sort of caraguatá, and its fibre is of a finer quality than that of its congener, but neither of them has obtained any importance in commerce owing to the cost of cleaning and separating the fibre from the leaves. Several attempts have been made but so far without any great success. From the interest that has been awakened in this product in European markets it would seem to deserve a more serious study, and the opinion seems to prevail that with improved machinery and more skilful administration more profitable results might be obtained." Any machinery that could successfully extract pine-apple fibre could also clean the caraguatá fibre. It is anticipated by those acquainted with the local circumstances that caraguatá fibre will some day form an important article of export from Paraguay.

OTHER BROMELIA FIBRES.

According to the "Kew Bulletin," 1887, April, p. 8:—

"There are several samples of a wild pine-apple (*Bromelia sylvestris*, Willd.) from the West Indies and Central America at Kew, but there is no record of their commercial value. A sample supposed to be from this plant was lately sent from Trinidad,

upon which the brokers reported as follows:—'Not yet in commercial use, but destined, we think, to a successful future; fine, soft, supple fibre, strong and good colour, ample length; say £30 per ton and upwards.'

"The fibre of the Jamaica Pinguin (*Bromelia Pinguin* L.) would appear not to be of high value. The plant covers hundreds of acres in the plains and lowlands of Jamaica, and an effort was made some time ago to prepare the fibre for commercial purposes. The report of brokers upon a sample of 90 lbs. was as follows:—'A long, towzelled, weak fibre, of bad colour, coarse, no strength, and only fit for breaking up. Similar to St. Helena hemp tow, but not so good. We should think £12 to £10 per ton the utmost value.' Several samples of this Pinguin fibre from Jamaica and elsewhere, cleaned both by hand and by machine, are to be seen in the Kew Museum, No. II."

Another bromeliad (*Karatas Plumieri*) with leaves 8 to 10 feet long, armed with distant, recurved teeth, is common in tropical America. It is a well-known and valuable fibre plant. It is said to be used by the Indians in making the finest hammocks in Central America, Guiana, and Brazil.

Bowstring Hemps.

The species of *Sansevieria* yielding Bowstring hemps have creeping rhizomes and a rosette of leaves of a fleshy character, sometimes flat, concave, round, or spear-shaped. The flowers are in spikes or clusters, white or green. The leaves are dark green, more or less succulent, and banded or mottled with white or black markings. They abound in a very valuable fibre, remarkable alike for fineness, elasticity, and strength. The Sansevierias are chiefly of African origin, but one at least may be Indian. Some of the species are already widely distributed in tropical countries. They are capable of being propagated very readily. Usually the rhizomes are divided and planted; plants may, however, be raised from seed, or, better still, from the leaves, which, if cut into pieces about two or three inches long, readily take root in moist situations. Plants may be put out at 3 or 4 feet apart. The first leaves for cutting may be produced in three to four years. In India, with *Sansevieria roxburghiana*, 1 lb. of fibre was extracted from 40 lbs. of small green leaves. It was calculated that "one acre would yield 1,613 lbs. of clean fibre at a gathering, two of which may be reckoned on yearly." So far Sansevieria fibre is not in commerce. It is, however, used largely in India—where it first received the name of bowstring hemp—in Ceylon, and on the West Coast of Africa for twine and cordage, and is regarded as most valuable. The fibre of *Sansevieria cylindrica*, known in Angola as "Ifé," is said to be the best fitted for deep sea sounding of any fibre known. The special merits of the fibre yielded by each species will be mentioned below.

Konje Hemp (*Sansevieria guineensis*).—One of the oldest and best known species. The mottled leaves are somewhat flat and leathery, about 3 to 4 feet long, 3 inches broad in the middle. On the Zambesi it yields "a valuable fibre similar to Manila hemp." It grows "in great abundance in many places, keeping to the shade of woods." In Mauritius, Jamaica, Cuba, and Trinidad it is semi-wild and yields excellent fibre. In Jamaica the return, under favourable conditions, is estimated at $1\frac{1}{2}$ tons of dry fibre per acre, of the gross value of £45. Samples received in this country from Trinidad, in 1886, were valued at £20 per ton, but the colour and strength were not normal. Good machine-cleaned fibre from Cuba is said to have realised £50 per ton.

Sansevieria longiflora.—This plant is a native of equatorial Africa. The leaves are like those of *S. guineensis*, but usually larger or flatter, and not invariably blotched with green. The best distinction is the individual flower, which is $3\frac{1}{2}$ to 4 inches long, while in *S. guineensis* it is only 2 inches long. Fibre from *S. longiflora*, grown at Kew, was described in 1887 as "very bright, clean, and strong; in every way a most desirable commercial article. It would compete with the best Sisal hemp for rope-making purposes. Value £30 per ton."

Pangane Hemp (*Sansevieria Kirkii*).—The leaf is very horny in texture, with a brown edge, much mottled on both sides. This species was discovered by Sir John Kirk, who states, "It grows abundantly near Pangane on the mainland opposite the island of Zanzibar . . . it is used by the natives and yields a long and useful fibre." The robust habit and large size of the leaf of this plant render it very valuable for fibre purposes. Under exceptional circumstances a single leaf will attain the height of 9 feet. Fibre from a plant grown at Kew was valued in 1887 at £27 per ton.

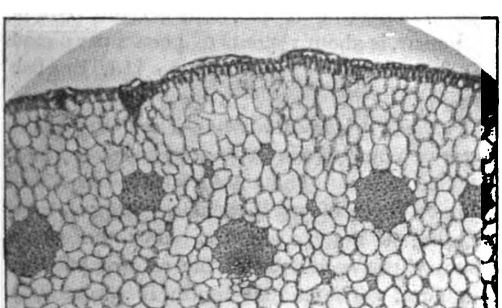
Neyanda (*Sansevieria zeylanica*).—This has long been cultivated in Ceylon. The leaves are semi-circular in transverse section, 1 to 2 feet long, dull green with a red margin, and copiously banded with white. The Singhalese use the fibre in numerous ways for string, ropes, mats, and a coarse kind of cloth.

Generally the fibre is prepared by retting or by simple beating and washing. The small size of the leaves, and the difficulty of handling them in large quantities, would render this species of less value commercially than any of the preceding.

Ifé Hemp *(Sansevieria cylindrica)*.—This is a most distinct and curious-looking plant. The leaves are quite cylindrical and solid, about 3 to 4 feet long, and about an inch in diameter at the base. When growing they look like a cluster of sharp-pointed stems. The species extends across tropical Africa from Zanzibar to Angola. The fibre, as already stated, is very valuable. Specimens prepared from plants grown at Kew were valued at £28 per ton. *S. sulcata* is very similar, but the leaves are more slender, with rather deeper vertical grooves. The fibre is slightly weaker, and valued at £26 per ton.

Moorva or Indian Bowstring Hemp (*Sansevieria roxburghiana*).—This plant was long confused with *S. zeylanica*, but Sir Joseph Hooker ("Flora of British India," vi., p. 271) has shown it to be quite distinct. The leaves reach 4 feet in height, narrow and semi-circular in transverse section, faintly clouded with black. The plant is cultivated for the sake of its fibre, and is the original bowstring hemp plant. The many uses to which the fibre is applied in India are fully described in Watt's "Dictionary of the Economic Products of India," vi., pt. 2, p. 460.

Fig. 11.



Bowstring Hemp (*Sansevieria sulcata*).

Transverse section through a portion of a leaf below the surface. Beginning from above are the cuticle, epidermis, and large-celled parenchyma. Embedded in the latter are the fibro-vascular bundles, varying in size. The cells are thick walled, with a small cavity.

As regards the foregoing species, it may be mentioned that the fibre of Sansevierias, in competition with Manila and Sisal hemps has possibly very little future before it. It is, however, so soft and silky, and possesses so much elasticity and strength, that it is well-fitted for numerous other uses. The fibre cells have a length of 1·5 to 3 mm. When more widely known and dealt with on an extensive scale, the Bowstring hemps are likely to prove most valuable. They flourish in rather damp situations, under the shade of trees, and extensive areas in West Africa and other countries could be devoted to the cultivation of these plants. When once established, they remain as a permanent crop, yielding regular cuttings of leaves two or three times a year.

Somali-land Fibre (*Sansevieria Ehrenbergii*).—This was first brought into notice in 1892, under the name of "aloe" fibre. The plant was determined at Kew as a species of *Sansevieria*, first collected by Dr. Schweinfurth between Athara and the Red Sea, and named by him *S. Ehrenbergii*, It is growing in large quantities in Somali-land, on the African coast opposite Aden. The leaves are solid, and almost circular, very stout and rigid, glaucous, and terminate in a strong, rather sharp point. Some are over 7 feet in height.

The fibre received in this country was described by Messrs Ide and Christie as "an excellent fibre of fair length, and with plenty of life . . . . with the exception of its colour, its preparation is perfect, and even as it is we value it to-day (27 June, 1892) at £25 per ton."

This plant differs from other species of *Sansevieria*, as it is evidently adapted to very arid conditions. It might, therefore, be found valuable for cultivation on land too dry for other produce. Lieut.-Colonel Stace mentions that there is any "amount of 'aloe' within reasonable distance [of the Somali coast], and it would be much improved by being properly cultivated." In preparing the fibre "the plant is not cut, but pulled out of the ground, and the sharp points cut off. It is then divided into two down the middle, and beaten with a stick until quite soft. The pieces are then drawn between two strips of wood fastened tightly together until all the pulp is squeezed out; no water is used. When quite dry, the fibre is ready for shipment." It is specially mentioned that the fibre must be extracted directly the plant is gathered, or it is spoiled.

Sisal Hemp.

Sisal hemp, Henequen, or Yucatan hemp, is produced by a species of *Agave*, native of Mexico, of which the common "American aloe" is the type. There are two, if not more, varieties: ultivated for fibre. The chief one

is the "Sacqui" (*Agave rigida*, var. *longifolia*). Plants were received at Kew in 1879, and again in 1890. The other is the "Yaxqui" (*Agave rigida*, var. *sisalana*). The former has leaves with side teeth, and a strong terminal spine; the latter has the terminal spine only; the edges of the leaves are smooth.

Cultivation.—These Agave plants are propagated either by suckers from the base of the stem, by seed, or by bulbils (called "pole" plants) produced on the flowering branches. The latter appear in the axils below the flower, and number many thousands. They remain on the parent plant until they are about four to six inches long, and sometimes much longer.

The land suited for the cultivation of Sisal hemp is entirely different from that required for Manila hemp. The best fibre districts in Yucatan possess an arid climate, with gravelly, stony, or rocky soils; they are only a few feet above the level of the sea; the summer heat is intense. It is claimed that the fibre is stronger and more abundant in dry, hot soils than in rich, deep soils. The plantations are formed with young plants about 18 to 20 inches high. These are put out in rows, at distances varying from 6 to 12 feet apart, equal to about 600 to 1,000 to the acre. Broad lanes are left here and there for the purpose of making roads or tramways, all converging on the factory, where the leaves are cleaned. A plantation begins to yield in three to five years, depending on the size of the plants when first put in, and the nature of the soil and cultivation.

Harvesting.—When the leaves are fit to cut 10 to 20 are taken from each plant, beginning from below. The cutting may be repeated two or three times a year according to the vigour of the plants. As soon as a plant shows signs of "poling" it is regarded as useless for fibre purposes. The pole is cut out and the remaining leaves are harvested soon after. To provide for the continuance of the plantation "it is the custom to place at the foot of each plant (when about three-fourths of its life are spent) a small plant which replaces the old plant when the latter is removed." The period of the life of a plant may extend from five to ten years or more. Cutting the leaves too severely will accelerate the poling of the plant and thus destroy its usefulness.

Extracting the Fibre.—The leaf-cutters are paid at the rate of 25 cents per day for 200 leaves. The leaves are conveyed from the fields to the factory either on mule back or by means of light tramways. Each mule carries 200 leaves each trip; a task of 10,000 leaves requires ten trips, with five mules each. On the tramway a mule can draw a waggon with 3,000 leaves and make five trips a day. Most of the large fibre estates in Yucatan are provided with light portable railways on the French Decauville system. The more common machine used for extracting the fibre is the "raspador." It is a rude piece of machinery consisting simply of a wheel like a four-foot pulley with a six-inch face. Across the latter are fitted pieces of brass an inch square and six inches long, running across the face about a foot apart. This wheel runs in a heavy wooden frame and makes about 110 revolutions per minute. The leaf is put in at one end of the machine and held by a strong clamp while exposed to the beaters. The pulp is soon crushed out of it, leaving only the fibre. The leaf is then reversed and the other end cleaned in the same way. The average work of one machine, requiring 1½ horse-power, is 7,000 to 9,000 leaves per day with two men feeding. It is estimated that 1,000 ordinary leaves will yield 50 pounds of dry fibre. Exceptionally they will yield 100 pounds, but from strong plants from five to seven years old 75 pounds would be a good yield. After the fibre is cleaned it is spread out in the sun to dry. It is afterwards pressed into bales by lever or screw presses or by hydraulic pressure. The latter method is becoming general. The bales vary from 350 to 400 pounds, with a cubic measurement of 22 feet. It is calculated that the total cost of growing and cleaning the fibre and of delivering it at Progresso, the port of shipment, is about 3½ cents to 4 cents per pound Mexican money (about 1¼d. to 1½d. English money).

Position of the Industry.—The fibre plantations in Yucatan are estimated to cover about 224,000 acres. The total yield in 1892 was 350,000 bales of 375 lbs. each, giving a total weight of 131,250,000 lbs. For the whole country, this would be at the rate of 760 lbs. per acre. The actual return is probably a good deal more, as the total area under cultivation is not all yielding fibre. The estimated yield of the Yucatan plantations in 1895 was 400,000 bales. A State duty of 20 cents per 100 lbs. is levied on hemp exported from Progresso. A detailed account of the fibre industry in Yucatan is given in the "Kew Bulletin," 1892, pp. 272-277, and 1893, pp. 212-218. The latter was prepared by her Majesty's Vice-Consul at Progresso. A general account of Sisal hemp plants, and

efforts to start industries in various countries is given in the "Kew Bulletin," 1892, pp. 21-40. Attached to this is a return of the average price per ton (spot value) obtained for Sisal hemp in this country for each month from January, 1879, to December, 1891. The following is a brief summary, based on this return, brought down to September, 1895:—

Year.	Highest.	Lowest.	Average for the Year.
	£ s.	£ s.	£ s.
1879..........	32 10	21 0	24 0
1883..........	29 0	24 0	27 0
1889..........	56 10	45 0	50 0
1894..........	20 0	15 0	17 10
1895........ Jan. to Sept.	17 0	13 0	14 7

The fall in prices, so marked in the United Kingdom since 1889, was equally prevalent in the United States. This will appear from the following:—

Price per lb. in New York, Dec. 31.	1892.	1893.	1894.	1895 to Sept.
	Cents.	Cents.	Cents.	Cents.
	6 to 6¼	3⅞ to 3$\frac{1}{16}$	2⅝ to 2¾	2¼ to 4⅝

Note added.—The monthly report on Sisal on the 16th September, 1895, showed a more favourable tendency. The spot value was £16 to £17 per ton.

Bahamas Pita.

The Sisal hemp or Pita industry of the Bahamas is of recent origin. It was regularly started about 1887. The plant is a native of Mexico, and identical with the "Yaxqui" of Yucatan—*Agave rigida*, var. *sisalana*. This is of a dark green colour, without teeth or prickles on the margin of the leaves, but with a black terminal spine. It produces suckers around the base, as well as bulbils and seeds on the flowering pole, as in the Yucatan plants. It is, therefore, well furnished with means for propagating itself over a wide expanse of country. Considerable interest has attached to the agency whereby the Bahamas became possessed of this valuable plant. The same plant is largely found in the south of Florida. This we know was brought there by Dr. Perrine from Yucatan, in 1836 and 1837. His intention was to cultivate it on a large scale for fibre purposes. About the same time he introduced 36 families from the Bahamas to settle on the land and supply the necessary labour. The Bahamas people were, however, frightened away by Indians, and could not be induced to return. Dr. Perrine himself soon after lost his life, and his plantations were abandoned.

The fibre plants were, however, destined to survive. They were carried about and planted as curiosities in gardens, and used as hedge-plants. Some found their way to Key West and to the neighbouring islands, and no doubt many were taken either by the settlers, or by some other means, to the Bahamas, as well as to Cuba and the Turks' islands. They are now present in all these islands. The introduction to the Bahamas from Florida is all the more probable because there has always been regular intercourse between them and the southern parts of that State. While, however, we give full credit to the probable introduction from Florida, it has been shown by Sir William Robinson, one of the most able of recent Governors in the West Indies, that some Pita plants were directly introduced to the islands from Yucatan by Mr. Charles R. Nesbitt, a former Colonial Secretary. This was in 1845. In 1851, just six years afterwards, when the plant had become established, "Mr. Nesbitt reduced a number of the leaves into fibre, and placed samples in the Nassau Museum." At the same time he sent specimens to England, and received very favourable replies as to their value, from London. It is evident that, for many years, Pita plants, all originally introduced by some means from Yucatan, have existed in the Bahamns. They have spread rapidly amongst the several islands and become, in some cases, troublesome to agriculture. It is evident also that, following Mr. Nesbitt's example, the plants were regarded as containing a valuable fibre, and likely to lay the foundation of an important industry. The difficulty was to obtain means for extracting the fibre in a satisfactory and remunerative manner.

In 1857, when Mr. C. J. Bayley, C.B., was Governor of the islands, there were sent for presentation to the Kew Museum, "Specimens of fibre, the produce of the leaf of the pine-apple and pita plants. The former is sent home," says the despatch, "in the hope of its applicability to the purpose of weaving; the latter from its abundance and uses as a material for the manufacture of paper." It is evident from this that the Pita plants were plentiful forty years ago. Many efforts were made by private enterprise, and also by the Government of the colony to draw attention to

the existence of the plants, and offer suggestions for turning them to account.

In 1879, Sir William Robinson endeavoured to utilise the pithy flowering-stem, or "pole" of the Pita for the manufacture of razor strops. A specimen sent by him is now in the Kew Museum. A set of Pita fibres was afterwards sent to the Fisheries Exhibition of 1883, under the auspices of Sir Charles Lees.

In the Hand-book of the Colonial and Indian Exhibition, 1886, p. 181, Sir Augustus Adderley states, "the Pita plant, the fibre of which is so largely exported from Yucatan, is common everywhere in the Bahamas. There is an important future for the colony in this article." In the Bahamas Court at the same Exhibition there were shown by the Government of the colony "a rope made from the fibre of the Pita plant;" by the General Committee at Nassau, "mats of fibre of the Pita plant," and "Pita fibre;" by Mr. W. W. Simonetti, "fibre of the Pita plant." This was during the Governorship of Mr. (now Sir Henry) Blake.

After the close of the Exhibition Sir Henry Blake, impressed with the valuable character of the Pita plant, brought the subject under the notice of the Secretary of State for the Colonies. After stating that "the question of the growth of the Pita plant for the production of fibre had assumed considerable importance," he asked "for any information available in this country as to the cultivation of Sisal in Yucatan and the methods adopted there for extracting the fibre." He added, "the plant grows here most freely and would soon materially increase our exportable productions if the fibre could be extracted with a small quantity of fresh water." These, as far as can be gathered, were the first practical efforts made to start a fibre industry. The Governor, in reply, was furnished with a copy of a report on the Sisal industry in Yucatan by Mr. Stoddart, then just published by the Government of Jamaica. It was pointed out that fresh water was not absolutely necessary to wash the fibre, or, at least, water was not generally used for that purpose in Yucatan.

In 1888, Sir Ambrose Shea, who had in the meantime succeeded Sir Henry Blake, took up the subject with singular energy and enthusiasm. Unconsciously, it may be, he took up the parable of his predecessors. It is, however, chiefly due to the personal effort and spirit of enterprise of this Governor that the industry has been so far established. He issued a circular dated the 22nd November, 1888, "to the Resident and Assistant-Resident Justices of the Bahamas on the position and prospects of a fibre industry which," he said, "is gradually being adopted by the people with a growing faith in its important bearing on their future welfare." From 1888 to the present time the progress of the industry has been comparatively rapid. The fibre was found to be of excellent quality, and during the period when white-rope fibres were in high demand it was valued at £56 per ton. Living plants of Pita were received for the first time at Kew, from Sir Ambrose Shea, in 1890. In 1891 it was reported that 4,100 acres were already planted. Several fibre companies were formed, the chief being the Bahama Fibre Company and the Munro Fibre Company. The head-quarters of the industry were at Abaco.

In 1892 the Governor reported that the "Fibre cultivation makes very satisfactory progress, and there are now about 8,000 acres planted out." A Commissioner was despatched in the same year to Yucatan "to study the whole subject of fibre cultivation and compare the circumstances of Yucatan and the Bahamas as regards, soil, climate, and the general healthiness of the plants." The Commissioner's report is published in the "Kew Bulletin," 1892, pp. 272-277.

From the Blue-book Report for 1893 we gather that the amount of land planted at the end of 1893 was 17,000 acres. "It may be expected that the annual increase would be about 6,000 acres. The value of the exported fibre was as follows:—In 1892, £592; 1893, £1,200."

The difficulty with regard to the fibre-extracting machine appeared to have been overcome. The Governor reported that "a machine manufactured by the Todd Company, of New York, has been at length found to work admirably, the fibre being cleaned perfectly at the smallest possible amount of waste." The small cultivators unable to get machines were said to be cleaning the fibre by soaking the split leaves in salt water for about a week, and then washing them by hand. About 50 lbs. to 60 lbs. of fibre could thus be cleaned in one day. The Governor continued:—"The generally accepted standard of 600 plants to the acre is being changed to 800, and in some cases to 1,000. If this increased number be not found to impede harvesting by the inconvenient crowding of the plants, the estimated yield of 1,200 lbs. per acre should of course be largely augmented."

It was unfortunate that the Bahamas industry was started when the price of fibre was exceptionally high. It led to exaggerated ideas being entertained as to the profits likely to be realised, and probably caused land to be planted that was unsuitable for the purpose. It also led to the enterprise being overloaded with capital, and to the cost per acre being increased beyond reasonable expectations of a suitable return. The same unfortunate mistake was made many years ago in starting the fibre industry in Mauritius. The result there was very tersely put by Mr. John Horne, F.L.S., in the following words:—"The fall in price in the European markets broke several local companies that were formed for working the 'aloe' estates. . . . There was too much money invested in them to pay."

It must always be borne in mind that all white-rope fibres are liable to violent fluctuations in prices. These, in the case of Sisal, have ranged from £56 10s. per ton in 1889, to £13 in 1895. The fall in 1895 was unprecedented, and was evidently the result of a combination of circumstances, such as the high prices in 1889 stimulating over-production, and the great depression in the trade of the United States. Bahamas Pita will have to compete with the combined supplies of Manila, Sisal, and New Zealand Phormium. The production of these is already on a very large scale, and, given adequate prices, the supply could be increased within a very brief period. The average output of Manila is about 600,000 bales per annum, equivalent to about 75,000 tons. The approximate cost per ton of the fibre, delivered for shipment at Manila, is £18 (2d. per English pound); this allows the workman, who cleans it by hand, a daily wage of about 10½d. to 1s. The average output of Sisal from Yucatan is 360,000 bales per annum, equivalent to about 60,000 tons. This is double what it was a few years ago. The average cost per ton delivered at the port of Progresso is £14—about 1½d. per English lb.; the daily wage of the peons for plantation work, cutting the leaves, cleaning by machinery, and drying, is 25 cents (Mexican money). This would be equivalent, at the present rate of exchange, to about 8d. English money. In many cases task work is given, when the peons earn up to 1s. per day, or a little more. New Zealand Phormium, up to 1893, was produced in large quantities. The highest output was in 1890, when it reached 21,158 tons; in 1893 it had fallen to 12,587 tons. The actual cost of production delivered at the port of shipment is not given. It must, however, be about £12 to £15 per ton, as the prices lately ruling have almost stopped the supply. As possible rivals of Bahamas Pita, we have here a total production of 151,000 tons of white-rope fibres. The wages paid in the production of Manila and Sisal hemps are lower than those usually paid to negroes in the West Indies, and a good deal lower than would be paid to white labour in New Zealand. There is no prospect that, given good prices, the supply of Manila and Sisal in the future will either be exhausted or diminished. The supply of Phormium will be kept back only as long as the prices fall below the cost of production. Enhanced prices would have the immediate effect of stimulating production, and, as we saw in 1890, Phormium fibre could be placed in commerce to the amount of 21,158 tons annually.*

Having pointed out the difficulties of the situation at the Bahamas, it is only right to point out the advantages which they possess as a fibre-yielding country. It is in their favour that the plant under cultivation is acknowledged to yield the best Agave fibre known in commerce. Moreover, it has no side teeth as in the plants generally found in Yucatan, and the process of harvesting can be carried on more rapidly and at less cost. Further, in Yucatan there are many species cultivated—some of less value. In the Bahamas the plants are all of the best sort, and on that account the fibre should obtain uniformly higher prices than Sisal hemp. The possible value may be 10 to 20 per cent. higher than good ordinary Sisal. It has been proved that the soil for the most part, and also the climate are well adapted for producing strong, glossy fibre. The samples of Bahamas Pita in the Kew Museums are the finest of any there. No Agave fibre can, however, be intrinsically superior to Manila hemp; but with the exception of this one article, Bahamas Pita should take the lead, both as a white-rope fibre, and for binder's twine. It is possible that the disadvantage as regards the higher wages paid in the Bahamas may be overcome by the use of more efficient cleaning machines, causing less waste, and turning out a larger quantity of fibre per day, thus reducing the

* The disadvantages here enumerated as likely to effect Bahamas Pita would tell with still greater force against supplies of similar fibre from other countries where plants have been introduced at a considerable cost and cultivated under less favourable circumstances. This applies to India, Australia, and many British possessions.

ultimate cost of production below that of Sisal. The anticipations under this head must, however, be qualified by the extent of unsuitable land already planted, and the heavy initial cost of establishing the plantations.

As regards freight charges to New York, they should be lower than for either Manila or Sisal. The position of the industry will, however, largely depend (1) on the effort made by all cultivators alike to produce a fibre of the highest quality to compete with Manila hemp or Sisal; and (2) by such rigorous reduction of the working expenses, that the fibre can be placed at the port of shipment below Sisal at any time, and, as a general standard, not exceeding the lowest prices of Sisal during the last three years. If these anticipations were fully realised, the future of the industry would not fail to be satisfactory.

[Note added.—In Messrs. Ide and Christie's "Monthly Circular" for the 16th September, 1895, Bahamas Pita sold at £16 10s. per ton. This is a slight improvement on recent prices.]

Bombay Aloe Fibre.

Bombay Aloe (*Agave vivipara*).—The plant is a native of tropical America, but widely spread in the East Indies. It is extensively used as a hedge plant in India, in Bombay, and the North-West Provinces. The leaves are very long, narrow, and concave, with rather distant, brown teeth, and a terminal spine. Numerous bulbils are produced on the flower spike, hence the specific name. When white-rope fibres were in high demand, the fibre from *Agave vivipara* was prepared rudely by hand, and shipped from Bombay. It was, from the first, practically unsaleable. In 1890 the stock in this country had accumulated to over 1,000 tons. The prices quoted were from £5 to £12 per ton. As pointed out in the "Kew Bulletin," 1890, pp. 50-54, well cleaned fibre from this species was really worth at that time from £25 to £30 per ton. The difference in price was entirely due to the character of the cleaning.

A very similar fibre to Bombay aloe fibre was imported this year from Natal under the name of South African hemp. It was probably yielded by *Agave americana*. It was of bad colour, not well cleaned, and almost unsaleable. It is useless to ship fibre of this character from any British possession.

Manila Aloe Fibre.

Manila Aloe (*Agave vivipara*).—The plant known locally as "Maguey" is the same as that yielding the Bombay fibre mentioned above. It is also cleaned by hand. The value of the Manila fibre has always been slightly higher than the Bombay fibre, owing to its being presented in a cleaner condition. In March, 1893, Manila aloe fibre was quoted at 17s. per cwt., while Bombay aloe fibre was dull at 8s. to 13s. per cwt. It was only possible to produce the former when the price of white-rope fibres was exceptionally high. Of late years it has almost disappeared from commerce. In the Philippines the aloe fibre is used for making strings for violins. It is important to distinguish between this fibre and Manila hemp yielded by *Musa textilis*.

Mexican Fibre or Istle.

Istle (*Agave heteracantha*).—This fibre is somewhat stiff and hard, and is described in commerce as "a unique substitute for animal bristles." It is used in the manufacture of cheap nail- and scrubbing-brushes. The plants yielding it belong to a well-defined group of Agaves, of which *A. heteracantha* is the type, with stiff, somewhat narrow leaves, having a distinct horny margin, with or without teeth. They are natives of Mexico. The fibre in commerce is known under the name of the districts from which it is exported. Jaumave produces a long, clean fibre regarded as the best; Tula a shorter and coarser fibre, while Matamoras produces a short soft fibre, somewhat woolly in character, probably produced by species of *Yucca*.

The head-quarters of the Istle industry is at San Luis Potosi. The fibre is exported from Tampico. The whole supply of fibre is obtained from wild plants which are abundantly distributed over the plains and rugged slopes of several States in Mexico. The peons collect the fibre when not otherwise engaged on the work of the haciendas. The central mass of leaves (the heart leaves) of the plant are torn out, and when a sufficient quantity are gathered together the work of extracting the fibre begins. This is accomplished entirely by hand. The chief instrument used is a blunt knife called a *tallador*. Between this and a hard wooden block each leaf is passed, "once for one side, once for the other, and a third time to give it a finishing scrape." When the pile of fibre has reached a certain bulk it is spread out in the sun to dry. It is afterwards packed in 200 pound bales and forwarded by mule trains, often over a distance of 170 miles, to the nearest port. A very interesting account

of the Istle industry is given by Mr. W. S. Booth in the "Kew Bulletin," 1890, pp. 220-224. Mr. Booth states, "the Agave and Yucca fibre industry is at present in its infancy. If intelligently followed it might become a very prosperous enterprise . . . where cheap labour and poor soil prevail. It might become still more prosperous by the use of economical machinery and intelligently managed plantations."

Other Agave Fibres.—The chief Agave fibres are Sisal Hemp, Bahamas Pita, Bombay and Manila Aloe fibre, and Istle. These have been already dealt with. In addition, some fibre is extracted in India, in the Mediterranean region, in South Africa, and more largely in Mexico, from the common American aloe (*Agave americana*). The fibre of this plant is very readily recognised; it has little strength, is poor in colour, and "gives" under moderate strain. It has a "tousled" appearance, and on that account is sometimes dyed black, and used as a substitute for horse-hair. Almost of an identical character is the fibre extracted from the Keratto of Jamaica and the West Indies (*Agave Morrisii*), which is described as "towy, not an even fibre, of very little strength, and undesirable." There are many other species of Agave, such as *A. sobolifera*, *A. Keratto* (distinct from the Jamaica Keratto) and *A. lurida*, from which fibre is occasionally extracted, but generally this is done in ignorance of the true fibre-yielding species. For long, white-rope fibre, the best Agave plant is undoubtedly that exclusively cultivated at the Bahamas (*Agave rigida*, var. *sisalana*).

Mauritius Hemp.

The Green or Fœtid Aloe yielding Mauritius hemp (*Furcræa gigantea*) was introduced as a garden plant from South America, about 1790. It is known amongst the French as *Aloës vert*. In 1837 it had established itself spontaneously in many localities in the island. About 1872, the quantity of plants growing on abandoned sugar estates suggested their utilisation for fibre purposes. The first exports were 214 tons, of the value of £4,934. Since that time, with some fluctuations, due to the ebb and flow of demand, the Mauritius hemp industry has steadily advanced. The value of the exports is now about £30,000 annually. The plant has much the habit of an "Aloe," but the leaves are bright green in colour, and with no teeth or terminal spine. The leaves are often 4 to 7 feet long, and 5 to 8 inches broad in the middle. The flowers are greenish white, on a branched peduncle or "pole" 10 to 20 feet high. Bulbils are produced as in some species of *Agave*. The plant is chiefly propagated by means of these. Regular plantations are established on the same plan as those described under Sisal hemp. Plants that have "poled" are replaced by strong young plants from nurseries. The life of a plant is about seven to ten years. They are, therefore, cut for about four or five years before they pole. Overcutting the leaves tends to cause the plant to flower and die prematurely.

Fibre Machines.—The hemp industry in Mauritius was greatly advanced by the invention of local machines, called *grattes*. They cost about £20 each, and are worked by steam or water power. The grattes are on the same principle as the *raspador* of Yucatan, and consist of a drum, with bolted blades, which revolves at a great speed in front of a feed table, on which the leaves are placed. One gratte is served by two men, who work alternately; one of them must be left-handed. The out-turn of wet fibre for each machine is, on an average, about 94 lbs. per hour; the out-turn of dry fibre per day of eight hours for each machine is 214 lbs. The average cost of producing a ton of fibre ready for shipment in 1890 is 225 rupees. A full account of the Mauritius fibre machine is given in the "Kew Bulletin," 1890, pp. 98-104.

Mauritius hemp is not largely used for cordage purposes. It has special applications on account of its fineness and lustre, and is much used for ornamental purposes. The prices have been well maintained, in spite of the depressed condition of most fibrous substances during the last two years. In March, 1895, the quotations were:—"Good white, 21s. to 24s. per cwt.; fair, 17s. to 18s.; common, 14s." The imports in 1893 were 1,373 tons; in 1894, 684 tons.

Furcræa gigantea has been largely planted at the island of Anguilla in the Leeward Islands, under the direction of Sir William Haynes Smith, K.C.M.G. The plantation is about 350 acres in extent, and the first crop of leaves will be shortly harvested. Should the price of Mauritius hemp be maintained, the Anguilla plantation is likely to be very successful.

Silk Grass.

Although this term is sometimes applied to some species of *Bromelia*, it is more generally

applied to *Furcræa cubensis*, one of the "green aloes," very similar in appearance to the plant yielding Mauritius hemp. It is a native of tropical America, and is cultivated in Jamaica and Tobago as a fibre plant. The leaves are 5 to 6 feet long, usually armed with strong prickles, but sometimes unarmed (as in the variety *inermis*), or with few prickles. The yield of fibre is at the rate of 2·5 to 3·15 per cent. Samples of silk grass fibre from Jamaica were valued, in 1884, at £27 per ton, and reported to be "superior to Sisal."

Another species, *Furcræa selloa*, with leaves 3 to 5 feet long, armed with brown horny teeth, is plentiful in Ceylon, but apparently scarce elsewhere. The fibre yielded by it is very similar to that of *F. cubensis*. Unlike the latter, however, it has no unarmed variety, and is therefore not likely to be widely cultivated for fibre purposes.

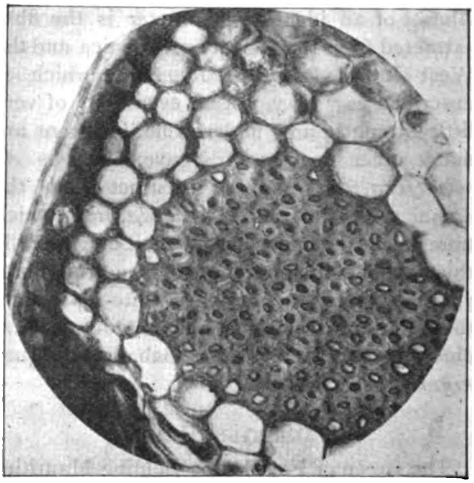
New Zealand Phormium Fibre.

The plant yielding this interesting fibre (*Phormium tenax*) is very variable. It belongs to the liliaceous order, and has very long, sword-like leaves, growing in opposite rows, and clasping each other at the base. There are two well-marked varieties. One has leaves 5 to 10 feet long, bright green above, glaucous beneath, with the flowers red; the other has shorter leaves, with the flowers yellow. The flowering stem is large, and alternately branched. It rises out of the centre of the leaves, reaching a height of 12 to 16 feet. The fruit is a three-valved capsule, containing two rows of small, flattened black seeds.

The Maoris are said to recognise about 55 sorts of the Phormium plant to which distinct names are given. The accepted number amongst Europeans is much less. Each shoot has five leaves, and about ten shoots go to a clump; there are therefore about 50 leaves in a clump. Exceptionally the leaves may be 10 feet high, but usually they are from 5 feet to 7 feet high. So far the Phormium plant is not regularly cultivated. The fibre is prepared wholly from wild or semi-wild plants. It is recommended to start plantations under favourable conditions, and make Phormium one of the established crops of the country. By such means it is anticipated that the leaves will be more uniform in character, and capable of yielding a better class of fibre.

Phormium has been the subject of extensive investigation in New Zealand for many years. Numerous experiments have been undertaken with the view of improving the methods of preparation, and extending the application of the fibre. The results have not been successful. The subject is still occupying the serious attention of the New Zealand Government. In 1893 the following premiums were offered:—(1) £1,750 for improvements in machinery which will materially reduce the cost of production of commercial fibre; (2) £250 for a process for utilising the waste products of the industry. The results of the trials in connection with these premiums have not yet been published. It is probable that experiments carried on in this country with fresh leaves would be more successful. It is to be expected that the conditions in New Zealand, in a comparatively new community, devoted chiefly to agricultural pursuits, are not so favourable for inventions as in the large manufacturing centres of England. A suggestion on this point is offered later.

Fig. 12.



New Zealand Phormium (*Phormium tenax*).

Transverse section through a fibro-vascular bundle immediately under the surface of the leaf. Beginning at the upper left-hand corner, the tissues are as follows:—Cuticle, epidermis, large celled parenchyma (shown white in section), then the dark mass of the sclerenchyma, containing thick-walled fibre cells with a small cavity. × 300.

It may be mentioned that the fibre of *Phormium* is neither a flax nor a hemp in the usual acceptation. It would be more correct to call it simply "Phormium fibre." It is one of the oldest exports of New Zealand. Between 1828 and 1832, although New Zealand was then visited only by whalers and a few traders, no less than £50,000 worth was shipped to Sydney alone. At that time the Maori hand-dressed fibre fetched a high price in the English

market, under the name of "New Zealand flax." The Maoris were careful in the selection of the leaves, taking only those in which the fibre was properly ripened, instead of cutting over the whole plant indiscriminately and at all seasons. Machine-dressed fibre did not come into commerce until 1861, and then only to supply the deficiency in Manila for rope-making. It is estimated that an acre will yield about ten tons of sun-dried leaves, and that the usual yield of fibre is at the rate of 12 cwt. per acre. Phormium is pre-eminent for its high yield of fibre; this is at the rate of 15 to 20 per cent. of green leaves. The old Maori fibre was so well prepared that it was capable of being made into damask and towelling equal to fairly good linen. Specimens of these are in the Kew Museum. The machine-dressed fibre is defective in many respects, and suitable only for the manufacture of twine for reaping and binding machines. It is felt that the full value of the fibre can only be obtained by the use of a combined scraping and chemical process applied to carefully selected and properly matured leaves. This is well brought out in the following extract from the "New Zealand Official Year Book" for 1894:—

"The greatest improvement of the present system will be effected by the cultivation and careful selection of the leaves, and by the substitution of a chemical retting process for the prolonged washing and sun-bleaching which at present obtain. . . . The sodic-sulphate process suggested by Mr. Cross appears to be the most promising. The advantage of this process over any other is the very high yield of fibre it achieves, which exceeds one-fourth of the weight of the green leaf, no other process having yielded more than one-sixth. The quality of the fibre produced resembles the native-made fibre in lustre and strength. For the future, if the phormium plant is to become a source of fibre supply for the world's market, its cultivation must be established in favourable situations. The natural supply is now difficult to collect, and still more difficult to renew and perpetuate."

The shipments of Phormium are variable. Owing to the improved demand for fibres generally, the number of Phormium mills in New Zealand increased from 30 in 1886, to 177 in 1891. The approximate value of the industry during the same period increased from £43,094 to £234,266.

The exports of Phormium for 1881, and for the years 1888-93, showing the quantities and values, were as follows:—

Year.	Tons.	£
1881	1,308	26,285
1888........	4,042	75,269
1889	17,084	361,182
1890........	21,158	381,789
1891........	15,809	281,514
1892	12,793	214,542
1893........	12,587	219,375

The figures since 1893 have shown a remarkable falling off in exports both to this country and America. The latter imported only 7,000 bales in 1894, as against 70,945 in 1893.

A careful investigation of Phormium fibre was undertaken by Mr. Cross in 1886. The results are published in the Reports of the Royal Commission of the Colonial and Indian Exhibition, 1887, pp. 373-376. As compared with Irish flax Phormium fibre contains a lower per-centage of cellulose, the actual figures being, Irish flax 80·2 per cent., Phormium 67·5 per cent. This cellulose in Phormium is also shown to possess a lesser stability than in flax. It is pointed out there is a very close structural resemblance between Phormium fibre and Manila fibre, so that in case Phormium may not be so useful as flax for the higher textiles it may be brought into more active competition than at present with Manila hemp as a white-rope fibre. The structural resemblance between Phormium and Manila hemp above noticed is corroborated by what takes place in commerce. "Phormium," writes one authority, "mixes well with Manila. When the demand in the States for binder twine runs on Manila then New Zealand Phormium is in such demand for mixing that it may go above Sisal in price."

The outlook in this direction is, however, not very promising. The supply of Manila, as well as Sisal hemp, could be considerably increased if prices went up, as there are large tracts of land still available for cultivation, and the labour supply is both cheap and abundant. Further, the question of freight has to be considered. Freight on New Zealand Phormium to the United States in 1892 was £4 10s. per ton, while on Sisal it was only £1. Again, by sailing vessel to the United States the freight on Manila was only £1 12s. 3d. per ton. By way of England it is more. The best opening for Phormium is evidently in the direction of supplying a good fibre for textile purposes, and here the field, at present at least, is not so fully occupied.

The prospects of the Phormium industry are very fully discussed in a paper presented to the Houses of General Assembly in New Zealand (H. 22, 1892), containing correspondence with the Agent-General in London. The latter states:—

"There are a number of skilled persons who, if they had sufficient inducement and full and proper opportunity [in this country] for ascertaining the nature of *Phormium tenax*, would direct their attention to the discovery of a means whereby the plant could be effectually and economically cleaned, so as to enable it to compete with Manila and Sisal."

He then offers the following suggestion:—

"It appears to me that what is wanted is the cultivation of the plant itself in this country to such an extent as would provide sufficient material for the purpose of supplying those whose skill and attention would be directed, on sufficient inducement being offered, to the discovery of proper machinery for preparing the fibre for the market."

It may be added that the plant grows very freely in the South of England, the South of Ireland, and many localities with a warm climate south of the isothermal line of 51° Fahr. A plot of about five acres in extent would be amply sufficient to supply leaves for experimental purposes. The importance of the interests concerned would fully justify the New Zealand Government to act upon the suggestion here given.

Palm-leaf Fibres.

Several species of palms with feather-winged or pinnate leaves, are utilised for the fine fibre contained in the leaflets. This fibre is fine and hair-like, very soft, and, when unbleached, closely resembles flax. It is composed of the fine fibro-vascular bundles running through the substance of the leaflet. It is deftly extracted by hand in the young state before it is hardened by exposure to the sun. The process is slow and tedious, but the value of the fibre is undoubted. It is remarkable for great strength and durability.

Oil-palm Fibre (*Elæis guineensis*).—The oil-palm is the most valuable plant in West Africa. It is distributed in a wild state over the greater part of tropical Africa. The yield in palm oil and palm kernels is of the annual value of about £2,000,000 sterling. The fibre from the leaflets of the oil-palm has long been known in West Africa. Only small samples have occasionally reached this country. A very clear and graphic account of the method of extracting the fibre is given in the "Kew Bulletin," 1892, pp. 62-67 (with wood-cuts). The young leaflet is, first of all, deprived of the mid-rib for a short distance below the apex, and it is then split horizontally so as to expose the fibro-vascular bundles. These are taken up one by one, and usually twisted at once into a thin cord. If not so twisted, they are kept in small tufts, and eventually made up into a bundle. The threads are "as fine and tenacious as human hair." It is a hard day's work to prepare six ounces of this fibre from 36 lbs. of the raw material. It is estimated that the actual cost of this hand-made fibre cannot be less than about £75 per ton. It is almost exclusively used for making fishing lines and fine cord. A sample submitted to Messrs. Ide and Christie, in June, 1891, was described as of "great strength and fineness, and, if really spinnable, worth £50 to £60 per ton." This must be regarded as one of the most valuable and lasting of tropical fibres.

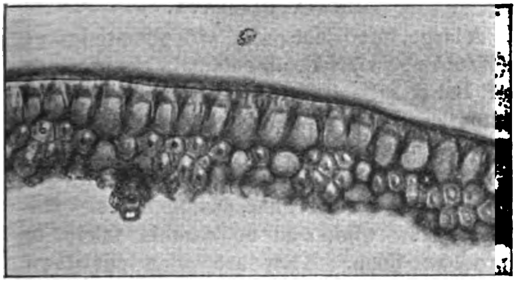
Gri-gri Fibre (*Astrocaryum* spp).—In the West Indies, at St. Vincent, and on the Atlantic slopes of Central America the Caribs extract a fibre from the young leaflets of the Gri-gri and other palms identical in character with that of the oil-palm. Demonstrations in extracting fibre were given by the Caribs sent from St. Vincent to the Jamaica Exhibition, 1891. It is evident that the process is widely known amongst native races. Everywhere the fibre is regarded as most costly and durable. A fine fibre is extracted also from the leaflets of *Astrocaryum Tucuma* in tropical South America. This is knitted by hand into a compact web of so fine a texture as to occupy two persons three or four months in its completion. The handsome hammocks afterwards made from the web sell for £3 each, or even double that amount.

Raffia.

Raffia is prepared by peeling off by hand the cuticle, or outside surface, of the leaflets of a Madagascar palm (*Raphia Ruffia*). This palm is widely spread in the island, chiefly in valleys, up to 4,000 feet. The pinnate leaves are 20 to 30 feet long; the narrow leaflets from 2½ to 5 feet long. The leaves are taken before they are fully expanded. The cuticle is peeled off on both sides. It appears as flat, straw-coloured strips, about half to three-quarter inch wide, and from 3 to 4 feet long. It is capable of being divided into fine threads. In Madagascar it is used for delicately-plaited goods, hats, mats for covering floors, and wrapping up goods. The loose strips are

extensively used in this country in place of Russian bast or tie-bands by gardeners and nurserymen. More recently it has been woven into superior matting, tastefully coloured, and used instead of tapestry for covering walls in London houses. Raffia usually reaches this country loosely plaited in hanks, weighing from 1½ to 3 lbs. each. These are made up into bales weighing 1½ to 5½ cwt. The preparation of Raffia is one of the most extensive industries in Madagascar. The men cut the palm leaves in the forests, and bring them home, the women do the rest. The fibre is cured the same day it is stripped. The price, in Tamatave, during 1894, was from 5 to 9 cents for the best Raffia, and about 2 cents less for red or discoloured Raffia. "Practically everyone doing business in Madagascar buys Raffia either for speculation, in barter for goods, on commission, or as agents."

FIG. 13.



RAFFIA (*Raphia Ruffia*).

Transverse section through the peripheral tissues of the leaf forming the commercial strips of Raffia. Beginning from above, the tissues are as follows: cuticle and epidermis; then the vertical cells of the palisade parenchyma; below these are the fibro-vascular bundles (four in number) the individual cells having strongly thickened walls. The strength of the strips is entirely due to the presence of these bundles.

Owing to the falling away of supplies from Madagascar, it has been sought to obtain Raffia from the Wine palm of the West Coast of Africa (*Raphia vinifera*). This already yields African bass, to be described later. Samples of West African Raffia were shown at the Colonial and Indian Exhibition, 1886. Small shipments have been made this year. The strips from West Africa are usually too short; they are curled together so as to resemble fine twine, and the colour is dull and too dark. If these defects could be remedied, there is no doubt West African Raffia would be in good demand. There is, possibly, a further source of Raffia from West Africa in the Black Run palm (which is known in India and Ceylon as the Palmyra palm). Excellent epidermal strips from this palm, nearly 7 feet long, are in the Kew Museum. These are longer than any received from Madagascar.

COROJO FIBRE.

A fine sample of Corojo fibre from Cuba was contributed by Messrs. Ide and Christie to Kew in 1890. At the time it was impossible to trace its origin. The strands of fibre presented a ribbon-like appearance somewhat resembling Raffia, but firmer and not so papery. They were extremely strong and capable of being divided into very fine tough filaments. On being handled it was noticed that the ribbons were armed with small spines as sharp as needles. These were not readily seen at first as they lie close to the fibre, but their presence was soon felt in passing the fibre through the hand. A careful examination showed that the fibre was formed of the epidermal layer of a palm leaf and probably derived from a species of *Bactris* or *Acrocomia* armed with prickles. In March of this year a further inquiry elicited the fact that the fibre was obtained from the unopened leaflets of the Gru-gru palm of the West Indies (*Acrocomia lasiospatha*). It is a remarkable fibre, and in point of tensile strength it surpasses even the oil-palm fibre already described. Its Cuban name is *Pita de Corojo*.

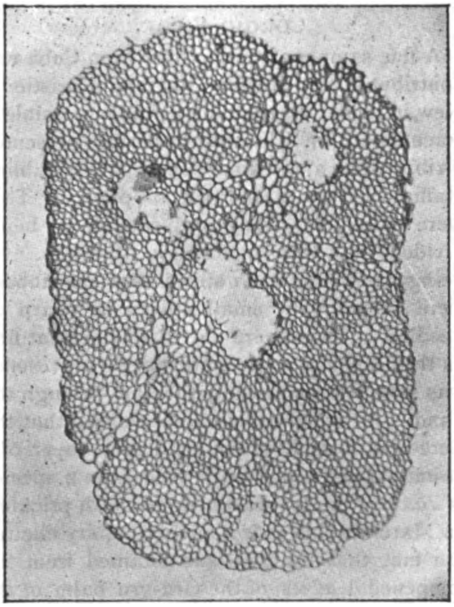
LECTURE III.—Delivered April 5, 1895.

IV. BRUSH AND MAT FIBRES.

Monkey Bass.

The hard, wiry palm-fibre obtained from *Leopoldinia Piassaba* is known as Para Piassava, or Monkey bass. The palm, when fully grown, is about 20 to 30 feet high. The fronds or leaves are feather-winged or pinnate, with rather rigid leaflets. The plant is found abundantly, but less than formerly, in the Amazon basin, especially in Barra de Rio Negro. It grows generally as isolated specimens in dense tropical forests, but is found sometimes in patches of several trees together. It is nowhere cultivated. The dilated margins of the petioles, where they clasp the stem, are produced into long riband-like strips, which afterwards split into fine, somewhat round fibres, about 5 or 6 feet long, entirely concealing the stem. These fibres, cleaned and combed by hand, form the piassava of commerce. There is very little preparation necessary after the fibre is collected in the forest. It is used for making brooms and brushes. Owing to the discovery of other sources of piassava, and to the palms becoming scarcer in accessible situations, Para piassava at present forms only 4 or 5 per cent. of the total fibre found in commerce. Para piassava nevertheless usually commands high prices.

Fig. 14.



Monkey Bass (*Leopoldinia Piassaba*).

Transverse section of a single strand of Monkey bass, apparently composed of three or more fibro-vascular bundles, coalesced together. The empty spaces represent the position of the vascular bundles. × 82.

Bahia Piassava.

A large, handsome palm, with pinnate leaves (*Attalea funifera*), abundant in the province of Bahia, Brazil, on river banks and moist situations, yields a fibre very similar to the Monkey bass of Para. The bases of the leaf-stalks separate into a long, coarse fringe, containing somewhat flat, flexible fibres. The trees grow wild, and no care is taken to preserve them. They are often cut down altogether in the young state for the convenience of getting the fibre. The latter is removed from the trees by means of a small axe. It is then "roughly heckled, straightened, cleaned, and made up into bundles of about 32½ pound each." The annual export from Bahia is about 7,000 tons, of the value of £117,664. Great Britain takes slightly more than one-half. The cost of the fibre delivered at Bahia is estimated at 5s. 7d. per arroba (32½ lbs.). The fruits of this palm are the Coquilla nuts of commerce, used for turnery purposes. An interesting account of Bahia piassava is given by Mr. W. S. Booth in the "Kew Bulletin," 1889, pp. 237-242.

Madagascar Piassava.

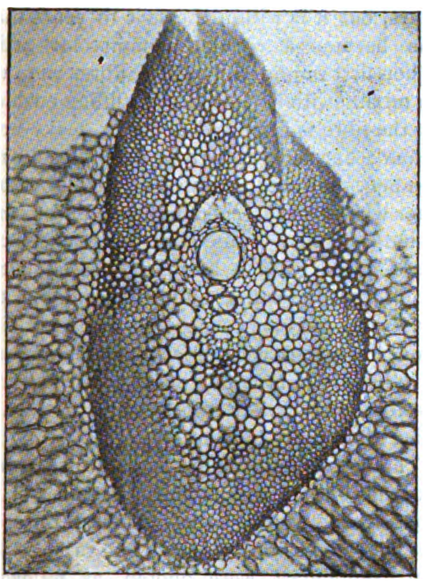
For many years a long, fine fibre, of a rich brown colour, has been obtained from Madagascar, closely resembling Para piassava. The plant was only determined last year, when it was described in the "Kew Bulletin," 1894, p. 358. It is *Dictyosperma fibrosum*, known locally as *Vonitra*. The fibre is finer and more flexible than Brazilian piassav

The quantity received in this country has always been limited, and latterly it has almost entirely disappeared. The high quality may be gathered from the fact that the last prices paid were £46 6s. per ton, with "good to prime" Bahia at £40 to £50 per ton, and "good" Palmyra at £30 to £40 per ton. When well cleaned, Madagascar piassava took rank as a first-class brush fibre.

West African Bass.

In 1890, Sir Alfred Moloney, then Governor of Lagos, drew attention to the possibility of obtaining a fibre from the bamboo or wine palm of West Africa. This is *Raphia vinifera*

Fig. 15.



West African Bass (*Raphia vinifera*).

Transverse section of a single fibro-vascular bundle of West African Bass, partly embedded in cellular tissue. The vascular portion in the centre occupies a large proportion of the area, and thereby tends to weaken the character of the fibre. × 50.

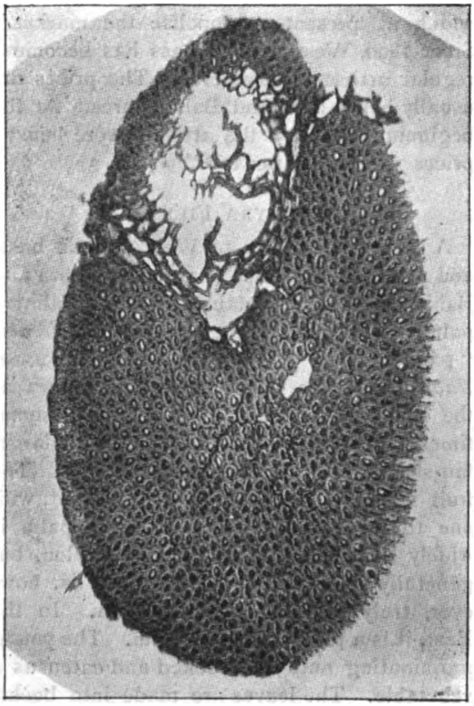
(already mentioned as likely to yield epidermal strips similar to Madagascar Raffia). The bamboo palm extends throughout many parts of West Africa. In Lagos alone it is estimated that it forms a considerable proportion of the forest vegetation over an area of 5,000 square miles. The fibre is obtained from the fibrous sheathing at the base of the petioles. It is readily obtained in lengths of 3 to 4 feet; the diameter of the individual fibres as found in commerce is from $\frac{1}{16}$th to $\frac{1}{30}$th of an inch. To understand the mode of occurrence of the fibre, the following is taken from Sir Alfred Moloney's account, published in the "Kew Bulletin," 1891, p. 4:—"When the leaves are cut away from the lower part of the palm, portions of the leaf-stalk are left adhering to it. These leaf-stalks encase the trunk, and project upwards and outwards, forming *chevaux de frise* all round it. From the fibre in these stumps the native fishing lines are made. It is extracted by simple soaking in water, and scraping. The process is very simple, and fully understood by the natives. It is the stronger portions of this fibre which are exported as West African bass." The Governor adds, "There is no reason why, with a population in the habit of preparing it, and a source of supply which may be regarded as practically unlimited, we should not be able to compete on even terms with the sources of supply which at present monopolise the market." Since 1890, West African bass has become a regular article of commerce. The prices are usually below Para and Bahia fibres. At the beginning of 1895 "the arrivals were heavy; prices £12 to £26 per ton."

Palmyra Fibre.

A fibre very similar to West African bass, and nearly of the same character as Para and Bahia piassava, is obtained from the Palmyra palm, called by the Portuguese, *par excellence*, "palmeira," or "the palm tree" (*Borassus flabellifer*). In West Africa it is known as the Black Run palm. It is very tall, sometimes, but very rarely, branched, with large, fan-shaped leaves with spinous petioles. The fruit is nearly as large as a cocoa-nut, with one to three seeds. The Palmyra palm is widely distributed in India and Ceylon, but generally in a cultivated state. It is, however, truly wild in tropical Africa. In the East, it is a toddy or sugar palm. The young germinating nuts are cooked and eaten as a vegetable. The leaves are made into books, which contain the classics of the Pali and Singhalese languages. The timber is hard, and very durable; it is used for umbrella handles and walking-sticks. From the base of the petioles, or the sheathing leaf-stalks, is obtained a stiff, wiry fibre. This was at first called "bassine," to distinguish it from bass and piassava fibres. It came into notice as a commercial article in 1891, when the high prices of piassava induced the production of substitutes. At that time even split rattan, stained black, was requisitioned as a brush fibre. Palmyra fibre has steadily increased in quantity, and, contrary to what was

at first anticipated, it has also risen in value. "The chief objection to Palmyra," wrote Messrs. Ide and Christie, in 1892, "is that it lacks straightness, but experiments are being made in this country to overcome this defect, and should they prove successful it is claimed by importers and dressers that Palmyra should, for wear, be found equal to the best Para." These anticipations have, to some extent, been realised. Palmyra now has practically taken the place of West African bass. The latter, on the 16th Sept., 1895, was "dull, business small, £14 to £23 per ton." Palmyra fibre, on the other hand, was "good, £26 to £34; medium, £22 to £25; common, £15 to £19 per ton."

FIG. 16.



PALMYRA FIBRE (*Borassus flabelifer*)

Transverse section of a single fibro-vascular bundle of Palmyra fibre. The vascular area is small, hence the greater strength of the bundle. The fibre cells are densely compacted, very numerous, and with thick walls. The durable character of Palmyra fibre is therefore evident. × 82.

The natives in Ceylon and India are now imitating the worst practices of the Indians of Brazil and sending consignments of Palmyra fibre to this country in a damp condition. The result is that, as one firm complains, "the bales, on opening, are found wet, and the fibre to a large extent perished and powdery." Should the practice continue, the industry will be seriously injured. The bales are press-packed, and iron bound; they weigh 1 to 3 cwts., and measure 10 to 30 cubic feet."

KITTOOL FIBRE.

The Kittool or Kittul palm of India and Ceylon (*Caryota urens*) is a stout handsome plant with a smooth annulated stem, 30 to 40 feet high. It has broad leaves, with the leaflets obliquely cuneate. The fruit is small and reddish. It is a toddy and sugar palm, and also yields sago.

Mr. J. R. Jackson, A.L.S., in "Commercial Botany," gives the following excellent account of the fibre yielded at the bases of the leaves of this plant:—"Kittool fibre," he says, "has been known in this country for some 30 or 40 years, but it is within the last 10 years that it has become a regular commercial article. When first imported, the finer fibres were used for mixing with horse-hair for stuffing cushions. As the fibre is imported, it is of a dusky-brown colour; but after it arrives here it is cleaned, combed, and arranged in long straight fibres, after which it is steeped in linseed oil to make it more pliable; this also has the effect of darkening it, and it becomes, indeed, almost black. It is softer and more pliable than piassava, and can consequently be used either alone or mixed with bristles in making soft, long-handled brooms, which are extremely durable, and can be sold at about a third the price of ordinary hair brooms."

The use of Kittool fibre is said to be spreading not only in this country, but also on the Continent. During 1895, Kittool fibre has not been much in demand. The values on the 16th September were quoted as follows:—"Long, 10d. to 10½d.; No. 1, 7d. to 7½d.; No. 2, 2d. to 2½d.; No. 3, 1d. to 1½d. per lb."

EJOO, OR GOMOTU FIBRE.

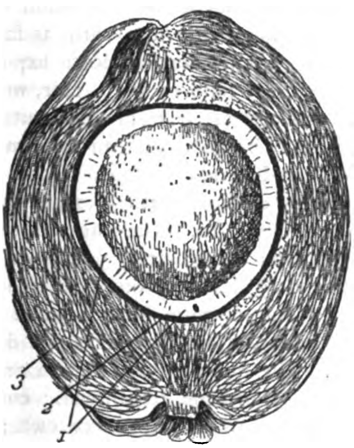
An erect palm, with pinnate leaves, the sago palm of Malacca (*Arenga saccharifera*), is found plentifully in Burma and the far East. At the base of the petiole is found a beautiful black fibre, known as Ejoo, or Gomotu fibre. There are several qualities: the coarsest is only fit for brush-making; the medium qualities closely resemble black horse-hair, and make excellent ropes and cables; the finest are used for caulking ships, stuffing cushions, and as tinder. Ejoo fibre is extensively used in the East. It undergoes no preparation, either before or after being twisted into ropes. It is remarkable for quality and cheapness, and is so durable

under water, that it has been recommended as a covering for telegraph cables.

COCOA-NUT FIBRES.

The Cocoa-nut palm (*Cocos nucifera*) is extensively cultivated in nearly all tropical countries. It exists in immense groves in Southern India, Ceylon, the Islands of the Eastern Archipelago, and Polynesia. Its cultivation is extending in the West Indies, and on the East and West Coasts of tropical Africa. The cocoa-nut palm is one of the first objects to be seen along the beach, and soon becomes one of the most familiar objects to travellers in the tropics. It is a valuable

FIG. 17.



COCOA-NUT (*Cocos nucifera*).

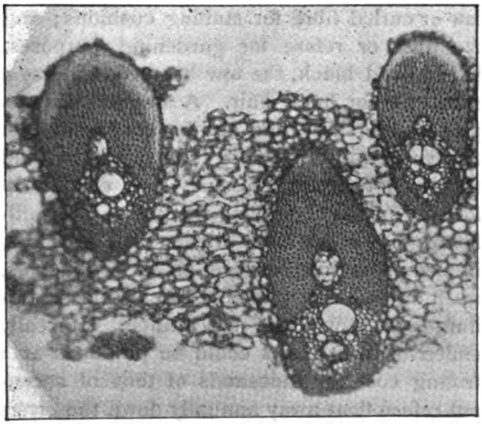
Vertical section through the fruit of a cocoa-nut palm. The central cavity contains the milk. 1, the white albumen or flesh of the cocoa-nut; 2, the endocarp or brown, hard, bony shell; 3, the pericarp forming the fibrous covering or husk of the cocoa-nut; this yields the coir of commerce. At the termination of the lower line 1 is the embryo pointed towards the base of the fruit. [In planting the cocoa-nut in the nursery it is, therefore, necessary to place it with the basal or stalk-end uppermost.] ⅓ n.s.

food plant for man and animals, and provides besides materials for the construction of houses, and numerous utensils in daily use. It has a cylindrical stem, usually gracefully curved, and attaining a height of 40 to 100 feet, surmounted with a crown of large feathery leaves. The plant is propagated by means of seed-nuts (the fruit); these germinate, if kept moist, in 3 to 5 months. The young plants are put out in their permanent places, when about 8 to 15 months old, at distances varying from 27 to 33 feet apart. The cocoa-nut begins to bear in 5 to 8 years. Usually, the nuts take from 8 to 10 months to mature before they fall from the parent plant. Each cocoa-nut palm bears from 30 to 60, and, very exceptionally, when well watered and manured, up to 100 nuts a year.

As shown above, the coir of commerce is yielded by the thick pericarp or outer fibrous covering of the fruit of the cocoa-nut palm. The word "coir" is said to come from the Malay *Káyar*, a twisted product. Kayer is also the Tamil for a rope. Although coir was known in Europe in the 16th century, it was not until about 1842 that it was brought prominently into notice. St. George's-hall, Windsor, in that year was laid with cocoa-nut matting on the occasion of the baptism of the Prince of Wales. Later a great impetus was given to coir manufacture by the Great International Exhibition of 1851.

Cocoa-nut fibre is tough, elastic, easily manipulated within certain limits, and eminently suitable for manufactures where lightness, cleanliness, and great indestructibility are required. It is understood that cocoa-nut fibre will not bear bleaching. Various shades of colour are, however, obtainable by using different descriptions of natural unbleached fibre. In an ornamental mat in the Kew Museum the various shades are obtained by using dark Fiji coir, medium-coloured Ceylon coir, and very light Cochin coir.

FIG. 18.



COCOA-NUT (*Cocos nucifera*).

Transverse section through a portion of the fibrous husk (pericarp) of the cocoa-nut. Three fibro-vascular bundles are shown embedded in cellular tissue. Each bundle represents a single fibre of coir when thoroughly isolated from the cellular tissue. There is a considerable resemblance in character, but not in size, between the fibro-vascular bundles in the husk of the cocoa-nut and those in the petioles of the Palmyra palm (Fig. 16). Hence, probably, the durable character of the latter. × 50.

Besides being made into rough cordage, coir is used in combination with wool to give richness and effect to hearth-rugs and carpet-

ing. It is also used for brushes and brooms for household and stable purposes, matting for sheep-folds, pheasantries and poultry yards, church cushions and hassocks, hammocks, clothes-lines, cordage of all sorts, string for nurserymen, nosebags for horses, mats and bags for seed-crushers, oil pressers, and candle manufacturers. Coir is one of the best materials for cables, on account of its lightness, elasticity, and strength. It is durable, and little affected by salt water. Of coir and coir-made rope, about 9,000,000 to 10,000,000 lbs. are annually shipped from India; much is prepared in Ceylon; but Cochin is noted as the port of shipment for the best quality of yarns.

Certain varieties or cultivated forms of the cocoa-nut are better suited than others for the production of coir. Cochin (a small native state on the Malabar coast) produces a bright, light-coloured coir, which fetches the best price. On the other hand, a good deal depends on the age at which the nuts are gathered, and the time which elapses before they are husked and cleaned.

In the process of separating the fibre, the following commercial qualities are produced: —The mat, or long fibres, used for spinning purposes; the shorter, or more stubborn fibres (bristles), for brooms or brushes; the tow or curled fibre for stuffing cushions; and the dust or refuse for gardening purposes. When dyed black, the tow has been used as a substitute for horse-hair. A singular use was proposed a short time ago for cocoa-nut dust or refuse. Taken before it is quite dry, and subjected to great pressure, it is capable of forming plates of varying thickness, like mill-board, only much more brittle. These boards, if used as backing for steel plates of ironclads, swell up on being punctured below the water-line, and soon close the orifice. If really effective, such plates could be produced at a trifling cost, for thousands of tons of cocoa-nut refuse float away annually down the rivers in India and elsewhere.

The first step in the preparation of coir is the removal of the husk from the hard interior shell. This is usually done by striking the nut on a pointed instrument stuck in the ground. A man can husk about 1,000 a day. The husks are then soaked in water. This is variously conducted. The water may be either salt, brackish, or fresh; in this the husks are kept for a lengthened period. The more recent method is to place them in tanks of water made warm with steam. The latter hastens the softening process, and improves the colour and quality of the fibre. Where machinery is used, the husks, when sufficiently soaked, are passed through a crushing mill, which flattens and crushes them ready for the extractor, or breaking-down machine. In the latter the fibres are completely disintegrated, and are then passed through a "willowing" machine, to free them from dust and refuse. It is calculated that, when treated in this country, 10,000 husks will produce 45 to 50 cwt. of "spinning fibre," and 9 to 13 cwt. of "brush fibre."

In Ceylon, 40 cocoa-nuts are said to yield 6 lbs. of coir; in Madras, 3 large coast nuts yield 1 lb. of coir; in the Laccadives it requires 10 small nuts to yield a pound of coir, measuring, when made into yarn, 35 fathoms. In 1889, an attempt was made to export coir from Lagos. A bale of loose coir, weighing 42 lbs., was prepared from 400 nuts. No attempt had been made to separate the "bristle" and "mat" fibres. Good Ceylon bristle fibre was then worth £30 per ton, and Ceylon mat fibre £10. The Lagos fibre, when separated, was valued at £15 and £9 to £10 respectively ("Kew Bulletin," 1889, pp. 122-132). The average annual value of coir goods exported from Ceylon is put down at £60,000. The quantity exported in 1884 was as follows:—Coir rope, 10,419 cwt.; coir yarn, 84,057 cwt.; coir fibre, 12,732 cwt.; total, 107,208 cwt.

The principal exports of coir from India are from the Madras Presidency. For the five years ending 1880-81 they were 271,934 cwt., valued at Rs. 2,179,767, while for the year 1881-82 the value was Rs. 2,354,202. The exports from the Malabar coast alone amounted to Rs. 2,243,000. "From these figures an idea may be obtained of the immense importance of Malabar aud the Laccadives as the chief seats of the Indian coir industry."

The approximate market value per ton of coir goods in London on the 16th September, 1895, were as follows:—

Coir yarn: Cochin, common to good, roping, £11 10s. to £14, weaving, fair to good, £20 to £25; Ceylon, fair to good, ballots and bales, £17 to £21.

Coir fibre: Cochin, fair to good, £14 to £20; Ceylon, clean, £8 to £9 10s.

Coir rope: 4½ to 6 inch, 2½ to 3½ inch, and 1½ to 1¾ inch, £11 to £14.

Bristle fibre: Medium, £18 to £21; good, £29 to £30.

Black Curled Fibre.

The only palm native of Europe is the Dwarf Fan Palm *(Chamærops humilis)*. This is the French *Palmier nain*. It is very abundant in North Africa, and particularly in the departments of Algiers and Oran. It forms extensive thickets in the dry alluvial soils of the littoral, and is very difficult to eradicate in any land where it is established. Once regarded as a troublesome and useless plant, it has of late years become a source of profit and commerce. The leaves furnish 50 per cent. of fibre, which is extensively used as a cheap substitute for horse-hair. A man can cut about 400 lbs. of green leaves per day. The fibre is extracted either by combing by hand or by means of drums with needles and knives worked by steam-power. The "green" fibre is twisted or curled in its raw state, and finds several applications. The "black" fibre is first dyed in baths of sulphate of iron and logwood; it is then twisted and again dyed. The local name is *crin végétal*. This fibre is said to possess two advantages over animal fibre, and these have led to its extensive employment. It is exempt from insect destruction, and 75 per cent. cheaper than horse-hair. There are large works in Algeria where the leaves are brought in large quantities, and the fibre cleaned on an extensive scale. "In Oran one factory prepares daily 60 bales of 2 cwt. each." In another, "by a particular process, a firm prepares black and brilliant *crin végétal*, without smell or dust, at the rate of 1,000 cwts. per month." The fibre is consumed principally in France, England, Germany, and the United States.

"The quantity of this vegetable hair shipped from Algiers in 1872 was 2,394,000 kilos. In 1887 the exports were as much as 15,304,126 kilos, valued at £88,900." The price of "black curled" fibre on the 16th September, 1895, was 9s. 6d. per cwt.; of "green," 6s. per cwt.

Spanish Moss.

Another "vegetable hair," more commonly known in the Southern States of America as Spanish moss, is obtained from a delicate, mossy-looking plant (*Tillandsia usneoides*), belonging to the pineapple family. This grows as an epiphyte on trees in tropical and sub-tropical parts of South America, the West Indies, and the Southern United States bordering on the Gulf of Mexico. In the West Indies it is called the "Old Man's Beard." The plant hangs in loose, lace-like masses on the branches and stems of several kinds of trees. The largest and most tenacious is said to be gathered from the cypress (*Taxodium distichum*). It gives these quite a funereal aspect. A living plant of this *Tillandsia* suspended from a dry block, and apparently deriving all its nourishment from the atmosphere, may be seen in the Tropical Stove (No. 9) at Kew. The "moss" is gathered in the Southern United States by negroes, who afterwards sell it to the factories, where it is cleaned and made into fibre. The single thread or fibre contained in the stem and leaves of this interesting plant is tough and black, almost identical with horse-hair. The fibre is prepared by soaking the plants in water until the cuticle of the leaf has decayed. It is then boiled in water, and washed until the black fibre is perfectly clean and glossy. It may also be prepared by simply burying the moss in earth for two or three weeks, and then washing in water. When well prepared, this fibre is not only frequently used instead of horse-hair, but is almost indistinguishable from it. It is largely used for stuffing purposes. The head-quarters of the industry is at New Orleans.

Pine Wool.

A brown elastic fibre is prepared in Germany, and in some parts of the United States, from the leaves of pine trees. In Germany, the leaves are obtained partly from what is known in this country as the Scotch Fir (*Pinus sylvestris*), and partly from the Corsican Pine (*P. Laricio*). In the United States the leaves of the Long-leaved or Resin Pine (*Pinus palustris*) are chiefly used. The industry was started at Breslau about thirty years ago. The pine leaves are collected in the fresh state and delivered at the factory at a fixed price per cwt. They are spread out and carefully picked over to get rid of portions of twigs and bark. They are then placed in a still with water to extract the oil, which forms an important item in the industry. This oil has the characteristic odour of pines. It is at first green, then yellow. There is a considerable demand for pine oil in commerce. The leaves, when removed from the still, are boiled with alkalis, broken in a "rubber," and dried. The fibre is then curled, passed through carding machines, and once more dried. The yield of "pine wool" is 13 per cent. of the weight of the green leaves. True "pine

wool" is said to retain the odour of the pine, is soft in texture, elastic, and durable. It is recommended as a surgical dressing; the finer sorts are used for making wearing apparel and blankets, and the coarser for carpets or mats.

A good deal of the material advertised as "pine wool," "fir-tree wool," and "pine forest wool," has been proved to be nothing more than cotton or sheep's wool stained of a brown colour to resemble the genuine article.

V. PAPER-MAKING FIBRES.

Paper-making depends entirely on vegetable fibres for the supply of cellulose, which is the essential element in all papers. Without cellulose there could be no paper. Paper is the result of felting together in the wet state of fibre cells obtained from the bast of exogens, and the fibro-vascular bundles of endogens, already described. In treating material for paper-making, the object of the paper-maker is to get rid of a portion or of all the extraneous substances other than pure fibre; the solvent for such extraneous matters may be cold or hot water with alkaloids or acids, with or without pressure; and according to the degree to which the ultimate fibre has been purified of extraneous matters, the better it bleaches, and the better the colour and quality of the paper produced from it.

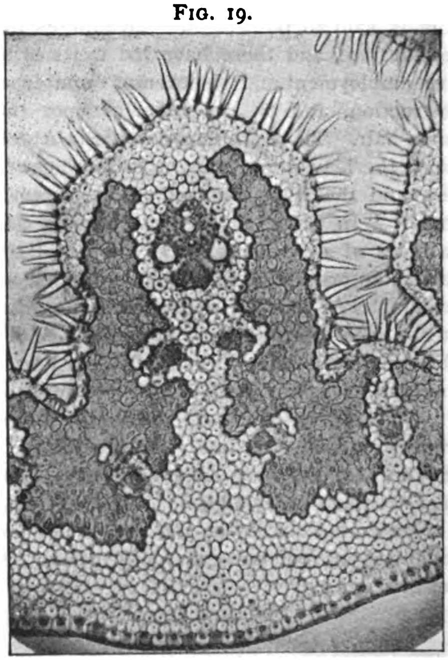
The quantity of paper produced annually in Europe is estimated at 1,000,000 tons, of the value of £30,000,000; of this sum one-half is the cost of the raw material.

The vegetable substances from which paper can be made are very numerous. The difficulty is to find a substance at once cheap enough to be used profitably, and abundant enough to secure a continuous supply. About 20 years ago, paper materials were becoming so scarce that the whole world was searched for them. Bamboos, straw, wild grasses, banana-stems, the rejections of spinning and weaving industries, tow and waste, jute butts, rags and cuttings of all kinds were utilised. No woollen goods nor any animal fibres, as they contain no cellulose in an appreciable quantity, could be used for paper-making. As showing the diversity of the material from which paper could be made, "a paper maker at the Paris Exhibition showed more than 60 webs or rolls of paper, each made from a different vegetable fibre." At the present time only two have come into use to a large extent; these are esparto and wood-pulp. Cotton and linen rags are regarded as very important, if not the most important, materials for paper-making purposes. They can, however, only be used profitably in the best papers. Cheap papers are largely made of mechanical wood pulp, mixed with kaolin or china clay. Such papers have no durability, and are quite unsuitable for bookwork.

ESPARTO.*

The esparto is a tufted grass (*Stipa tenacissima*) allied to the ornamental feather-grass. The leaf sheaths are hairy internally, and hence esparto can be easily distinguished from a somewhat similar, but inferior grass (*Albardin*), formerly introduced instead of the genuine article. Esparto grows in dense clumps, with the culms from 1½ to 2½ feet high. It thrives extremely well in sandy and rocky soils, at moderate elevations, near the sea coast. It is abundant in North Africa, and in some localities of Southern Spain. The plants are growing wild over extensive tracts of country, and the only expense is, practically, the cost of collecting and shipment.

FIG. 19.



ESPARTO (*Stipa tenacissima*).

Transverse section of a portion of a culm of esparto, showing one of the projecting ribs on the inner side with a bay on either side, all armed with silicious hairs. The darker areas are the chlorophyll-bearing cells. The whole of the lighter portions occupying the lower part of the field, and extending upwards between the chlorophyll-bearing cells are the thick-walled fibre cells. × 150.

* The Spanish form of *sparton*, cordage.

From very ancient times esparto was used for making carpets, ropes, baskets, nets, and as a substitute for horse-hair. These were prepared from the long leaves grown inland, now not considered so good for paper-making as those growing near the sea coast.

The harvest of esparto commences in August and lasts up to October. About 10 tons of dry esparto may, exceptionally, be obtained from one acre. The four sorts of commercial esparto are named after the country of origin. The Spanish is regarded as the best, then come the Algerian and Tunisian, and lastly the Tripoli esparto. A small quantity occasionally comes from Morocco. Spain for a long time supplied the whole of the esparto of commerce, but latterly its exports are small compared with those of North Africa. The area under wild esparto in Algiers is estimated at 2,500,000 acres, but a good deal is beyond reach of facilities for transport to the coast.

The extensive use of esparto for paper-making is greatly due to the exertions of the late Mr. T. Routledge. He commenced with a few tons at the Eynsham mills, about 40 years ago. It is of interest to note that the paper for the number of the *Journal of the Society of Arts* for November 28, 1856, was made of it. The use of esparto extended very gradually. The annual value has, however, of late reached nearly a million sterling. The United Kingdom has, hitherto, monopolised the supply. The imports for the last thirty years have been as follows:—

1861	891 tons.
1870	89,156 „
1880	191,229 „
1890	217,078 „

The highest imports were in 1888, when they reached 248,836 tons. Since 1890, the imports have somewhat declined. Last year, 1894, they were only 184,910 tons.

There is apparently a disposition, except in Scotland, to give up the use of esparto in favour of the cheaper and inferior wood-pulps. The fibres in esparto are easily dissolved and bleached. An authority on paper-making writes:—"They felt readily, and yield an excellent pulp, which is employed alone or mixed with rags, wood-pulp, or straw. They furnish a paper pliant, resistant, transparent, and of great purity; thicker than other papers of the same weight, and forming a good printing and writing substance." The falling away in the use of esparto for paper-making, and the substitution of cheap paper-pulps, must therefore be regarded as likely to lower the general quality of English-made paper.

The following Table will show the comparative value of esparto in 1878 and 1895 respectively. The great falling off in prices of late years is due, as suggested, to the competition of wood-pulp. The figures are compiled from the circulars issued by Messrs. Ide and Christie, 72, Mark-lane, E.C.:—

Quality.	Price per Ton.	
	1878.	1895.
	£ s.	£ s. d.
Spanish, fine to best, average ...	10 5	5 2 6
„ fair to good, „	10 0	4 12 6
Algerian—		
Oran, first quality, „	7 10	3 12 6
„ fair to good, „	7 0	3 2 6
Tripoli, hand-picked, „	6 10	3 9 6
„ fair average, „	6 0	3 5 0

Bhabur Grass.

Bhabur grass (*Ischæmum angustifolium*) might be regarded as the esparto of India. It closely approaches the latter in habit and in the technical qualities necessary for paper manufacture. The late Mr. Routledge tried Bhabur in 1878. His opinion was favourable:—"A small quantity of bleach," he said, "brings it up to a good colour. The ultimate fibre is very fine and delicate; rather more so than esparto, and about the same strength; the yield, however, is 42 per cent., somewhat less. . . . I may venture to say that it will make a quality of paper equal to esparto." Since 1878 Bhabur grass has become very largely used in India. At the present time it affords—as stated by Dr. King, F.R.S., who first called attention to it—"the chief raw material for paper-making in the neighbourhood of Calcutta and other parts of India." The grass is very common in the Siwalik range and in the Bhabur forests of the Gharwal and Kumaon Himalaya. It is found in the forests of Chota Nagpur. The prospect of utilising the grass would be, no doubt, improved if it were cultivated. This is readily practicable. It yields at present two crops in the year, one in September, and the other in October or early in November. It might yield a third if irrigated. ("Kew Bulletin," 1888, pp. 157-160, with plate.)

Straw.

Although, properly speaking, it is the straw of esparto that is used for paper-making, it is so superior for this purpose to ordinary straw, that it deserves to stand alone. The straw of numerous cereal grasses is employed where obtainable: rice straw is used in Asia; wheat, oat, and other kinds in Europe. "For low papers straw commands a market, but as a mixer it is inferior to esparto, the internodes or knots being exceedingly troublesome, and difficult to get rid of."

Wood-pulp.

The deficiency in paper materials led to the use of pulp, made from the wood of certain trees. The woody stems of trees are composed of (1) vessels or long continuous tubes with peculiar markings, due to the walls being unequally thickened; (2) fibrous cells composed of long, thick-walled cells with sharply-pointed ends, the wall is thickened nearly all over, but there are a few narrow pits where the wall is left thin; (3) of woody parenchyma having cells with square ends with rather thick walls and small pits. The woody character of the fibrous cells is due to the presence of lignine. This renders them much harder and stiffer than those of pure cellulose, as found in cotton. In the manufacture of wood-pulp the object is to break up and reduce the wood cells so as to form a suitable material for paper-making. Mechanical wood-pulp is prepared by merely grinding the wood of certain trees, such as poplar, aspen, spruce, and fir, into a fine creamy condition, and afterwards washing out some of the impurities with water. There is still left a large amount of lignine and other substances which are injurious to the quality of the paper. Mechanical wood-pulp is often of sufficient whiteness to be used for what are called white papers, but such papers become discoloured with age, and perish on exposure to a damp atmosphere. Wurster has devised a test based on the depth of colour given by these papers, so that he can arrive at a quantitative estimation of the proportion of mechanical wood-pulp contained in them. Chemical wood-pulp is produced by treating the ground wood with chemicals to remove the resin, and all ligneous and mineral deposits, leaving only the fibrous cells composed of almost pure cellulose. The various sorts of chemical wood-pulp (often called wood cellulose) are named according to the chemical agents employed in their manufacture. These may be *sulphite* pulp, *soda* pulp, or *sulphate* pulp, according as they are prepared either with sulphite of lime, caustic soda, or sulphate of soda. The Common Spruce and the Silver Fir are the chief species that supply the chemical wood-pulp of Europe, while the White Spruce, Black Spruce, Canadian Hemlock, White American Pine, and Silver Fir, furnish the chemical wood-pulp of the United States and Canada.

The rapid progress made in the use of wood-pulp for paper-making is one of the most remarkable amongst modern enterprises. In the United States, in 1886, only about 97,000 tons were produced. During 1894 the quantity was estimated to exceed a million tons of the value of £5,000,000. Mr. S. P. Eastick states that the pulp necessary for the daily editions of one New York paper absorbs the timber from about seven acres of an average forest. Although at first only intended for paper-making, wood-pulp is capable of being so hardened that it can be successfully employed for the manufacture of furniture, carriages, floor-covering, kitchen utensils, &c. It can also be dyed any colour and rendered fire and water-proof.

The most suitable wood for the manufacture of chemical wood-pulp is derived from the *Coniferæ*. Hence the pine forests of the United States and Canada, as well as those of Europe, have considerably increased in value. In many cases the small logs and waste of saw-mills can be utilised for wood-pulp. Sawdust has been found unsuitable, owing to the difficulty of treating it effectually. Canada is very advantageously placed for a wood-pulp industry. It possesses, as one authority states, "vast forests of suitable wood, whose quality cannot be surpassed; it has magnificent rivers for transporting logs and produce, and enjoys the advantage of numerous sea-ports and low ocean freights to Europe."

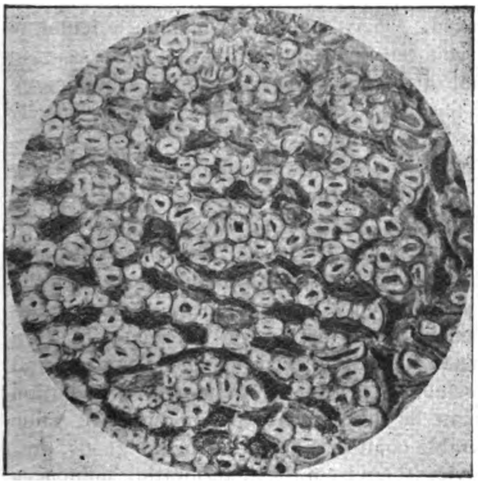
Norway and Sweden take the lead in the wood-pulp industry of the Old World. The estimated exports of mechanical wood-pulp for 1894 were about 240,000 tons of the value of £500,000. This is nearly double what it was six years ago. There were 61 machine wood-pulp factories, of which three were attached to cardboard factories, and ten to paper factories. A large quantity of the Norwegian wood-pulp is shipped to the United Kingdom, but France and Germany also take increasing quantities. In the preparation of chemical wood-pulp or cellulose there were ten turning out sulphite pulp, and four turning out soda pulp. The exportation in 1894 were about

34,000 tons of dry, and 10,000 tons of moist pulp, against 32,000 tons of dry and 13,000 tons of moist in 1893. The annual value of the chemical wood-pulp industry is about £320,000. A large proportion of this pulp is shipped to the United States.

Nepal Paper Plants.

Although, at present, there is little prospect of any paper material competing successfully with wood-pulp, it is desirable to mention a few fibres that possess exceptional merit. Of these, the most prominent in India is the Nepal paper plant, *Daphne cannabina* (also known as D. papyrifera). This is a shrub or small tree found on the Himalaya, between altitudes of 3,000 and 10,000 feet, on the Khasia and Nage hills, and it is one of the most abundant bushes on the hills between Manipur and Burma. It is said that the well-known Nepal paper is made from the bast fibre of this and other species of *Daphne*, and of the allied *Edgeworthia Gardneri*. Dr. Royle states that, at the Exhibition of 1851, a sample of Nepal paper was shown of such size as to occasion universal surprise. He states:—"This paper is remarkable for its toughness, as well as its smoothness." An engraver, who tried some of this paper, stated that "it afforded finer impressions than any English-made paper, and nearly as good as the fine Chinese paper which is employed for what are called India paper proofs." As Daphne paper can be purchased throughout India, it is evident that the manufacture of it by the hill tribes, who alone produce it in quantity, must be very extensive. Dr. Watts remarks, "Daphne paper will endure for many years under a treatment that, in a few weeks, days, or even hours, would render the modern papers produced in England perfectly worthless."

Fig. 20.



Nepal Paper Plant (*Daphne cannabina*).

Transverse section through the bast area, showing the characteristic disposition of the fibre bundles. The cells vary in diameter, in thickness of the wall, and the size of the cavity. × 150.

Paper Mulberry.

The Paper Mulberry (*Broussonetia papyrifera*) is widely distributed throughout Eastern Asia and Polynesia. It is extensively used for making paper and also the Tapa cloth of the South Sea Islands. The Japanese propagate the plant very much as willows are grown in England. They use only the young shoots for the manufacture of paper. Mr. Routledge stated that the bast of the Paper Mulberry was nearly, if not quite, the best fibre he had ever seen. It required very little chemicals and gave an excellent yield—62·5 per cent. in the grey and 58 per cent. bleached. The Japanese use paper made from this plant for a variety of purposes, such as umbrellas, lanterns, and books of all kinds. In the Kew Museum is a specimen of Tapa cloth, originally part of a roll that measured two miles in length by 120 feet wide. This belonged to the King of Tongataboo, one of the Friendly Islands. A paper very similar to that prepared from the Paper Mulberry is obtained in Siam from *Streblus asper*. This is a weedy-looking tree abundantly distributed throughout India, Ceylon, and tropical Asia. White Streblus paper is used for legal documents and Government correspondence, while a black paper written upon with talc is used for rough drafts and for taking evidence in native law courts ("Kew Bulletin," 1888, pp. 81-84).

VI. CELLULOSE INDUSTRIES.

In concluding these lectures, it is desirable to say a few words on the industrial application of cellulose other than for fibre purposes. We started by regarding cellulose as the essential element in all fibres. We have seen, in the course of our inquiry, that the larger the per-centage of cellulose the better the fibre. It is not too much to say, in regard to the manifold uses to which cellulose can be put, that it is one of the most important bodies in the whole realm of Nature. The most abundant and accessible form of pure cellulose is the floss of cotton and the silky seed

hairs of many plants described in the first lecture. It is also found almost pure in well-bleached fabrics made of linen, hemp, and in the best, unsized, white paper. The use of cellulose, now to be dealt with, is based on the facility with which it can be dissolved or gelatinised in the presence of certain metallic compounds, or by means of nitric and sulphuric acids. By means of the latter, it yields the cellulose nitrates which find a number of highly important uses in explosives, such as gun-cotton, and when associated with nitro-glycerine in the newer explosives known as blasting gelatine, ballastite, and cordite. Schultze Powder is prepared by macerating soft timber until only pure cellulose remains. This is nitrated with acids, and forms a powerful powder that is almost smokeless. Other nitrates of cellulose are worked up with camphor and similar substances into celluloid and xylonite, forming plastic masses which can be cut and moulded into articles of the most varied form and use. Besides these there is collodion (pyroxylin), a nitrate of cellulose dissolved in ether-alcohol, forming transparent solutions, which, on evaporation, leave a film of considerable elasticity and tenacity. There are surgical or medicated collodions and photographic collodions. The cupra-ammonium solutions of cellulose are utilised in the production of what are known as "Willesden" goods. "Vegetable textile fabrics, when passed through a bath of the cupra-ammonium hydroxide are 'surfaced' by a film of gelatinised cellulose, which retains the copper oxide in such a way that it dries of a bright 'malachite' green colour. By this treatment the fibres are further compacted together, and the fabric acquires a water-resistant character. The presence of the copper oxide is also a preservative against the attacks of mildew, insects, &c. If the fabrics are rolled or pressed when in the gelatinised condition, they become firmly welded together on drying, and a variety of compound textures are produced in this way." (Cross and Bevan, *Cellulose*, p. 13.)

Another application of soluble cellulose is the product known as artificial silk. This is prepared by means of an apparatus which allows the soluble cellulose to be drawn off from the end of a glass tube on to a light wheel revolving at a definite rate. By this means the thread is kept continuously at a uniform diameter. Several threads being twisted together in the usual way of "silk-throwing," the artificial textile thread is produced. "Artificial silk has been found to have a tensile strength equal to 70 per cent. of that of the natural product of the same degree of fineness." It is capable of being largely used industrially.

"Viscose" is the commercial name given to an acetate solution of cellulose likely to prove of great value. A series of preparations of viscose shown before the Society of Arts indicated varied uses for this substance. In the dry condition it is of a horny character, extremely hard, and very durable. In thin sheets it can be used for book-binding and resembles the finest parchment. In solution it can be used to size paper and give a fine durable coating to jute and hemp goods, preserving them from the deteriorating influences of a damp atmosphere. Viscose also gives a good surface appearance to cotton goods and at the same time adds greatly to their strength.

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